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Business & Commercial Aviation

July, 1995

SECTION: TECHNOLOGY; Vol. 77, No. 1; Pg. C2

LENGTH: 1817 words

HEADLINE: Trend Monitoring Comes of Age

BYLINE: By DAVID ESLER

HIGHLIGHT: Knowing what's happening inside your engines and systems can save you a bundle-or even your life.

BODY:

Almost from the moment Orville and Wilbur first fired up the hand-built piston engine mounted on the lower wing of their Flyer biplane, pilots and mechanics have longed to know what was going on inside their aircraft's powerplants and systems.

As aviation technology evolved, so did cockpit instrumentation; but the actual condition of an engine's or system's health frequently remained elusive until overhaul or until something failed catastrophically. While some pilots claimed to know their recip-rocating engines' internal machinations from the color of the exhaust plumes, such techniques were largely guesswork.

It wasn't until the last generation of piston-engine airliners entered service in the mid 1950s that a scientific approach to condition analysis emerged. The advent of onboard monitoring equipment (like oscilloscope-based engine analyzers) and formulation of trend-monitoring procedures finally allowed flight engineers and maintenance departments to accurately assess engine condition and predict with some assurance how long a powerplant would last.

But the accurate monitoring of the health of airframe systems had to wait largely for the application of computer technology a decade later. Lockheed's huge C5A Galaxy military hauler-a landmark technological achievement in its own right-was one of the first transport aircraft to enter service with an **onboard,** multi-channel engine and systems condition-monitoring **computer** designed into the airframe. Capable of providing real-time information to flight and ground crews, the system featured diagnostic analysis and was backed up by a maintenance database, or library, for inflight reference. Meanwhile, refinement of microprocessors in the 1970s spawned smaller, lighter monitoring equipment and more sophisticated remote sensors for both military and civil aircraft.

MONITORING THE FLEET Managing huge fleets of aircraft, the armed forces and airlines were quick to embrace the concepts of condition monitoring and trend monitoring. While safety played a role in propagating trend monitoring, it was economics that drove the need to prolong engine and systems life as long as possible, since even a 50-hour extension in on-condition maintenance can represent significant savings when spread across a large fleet.

It took a little longer for the concept to trickle down to general and business aviation, but it gained a foothold when engine manufacturers and warranty companies began to offer so-called "power-by-the-hour" mainten- ance packages in the 1970s. To qualify for these long-term protection programs, operators were required to participate in trend monitoring so that engine builders, service centers, and warranty providers could track the health of customer engines, identifying potential problems before they developed into expensive fixes or compromised safety.

Two approaches to trend monitoring have evolved to serve the needs of business and general aviation: (1) Manual recordkeeping and analysis of data from conventional cockpit instrumentation, and (2) Installation of automated hardware aboard the airframe to accomplish the monitoring function with little active involvement of flightcrews.

The former had its roots in the piston-engine airline era, when cockpit crews kept detailed engine logs, periodically recording power parameters in flight and after shutdown for later analysis by company maintenance departments.

Today, many corporate flight departments engage in the same manual data entry to support their in-house maintenance programs or satisfy power-by-the-hour service coverage. Customarily, parameters sampled for modern turbofans include core speed, ITT and fuel flow.

THE ROLE OF THE TREND HOUSE Frequently, the collected data are transmitted via telephone or computer modem to specialized companies for analysis. Called 'trend houses,' these firms contract either directly with operators or with engine manufacturers and service pro-viders. Their trained analysts plot and interpret engine performance data, usually with the help of sophisticated computer programs. By comparing performance to established models for the specific engine type (frequently provided by the powerplant manufacturer), they are then able to discern trends.

Where warranted by consistent values that fall within the engine's nominal performance envelope, they can then recommend extensions in hot-section inspections and overhaul intervals, provided of course that the FAA has approved the engine for on-condition maintenance. However, if the analysts see one or more parameters diverging from established performance models-say, a sudden rise in ITT-they immediately alert operators and service contractors to the presence of a potential problem.

Often, by studying the trends, an experienced analyst can even pinpoint the nature of the glitch. It may be something as benign as an out-of-calibration instrument sensor or as serious as a fractured fuel nozzle carried downstream by the gas flow.

If calculated trends in a high-time engine were suddenly to improve, where a certain amount of degradation from normal wear would be expected, one analyst told B/CA, it might be an indication of turbine blade "creep" (elongation of blades). This would be a "flag" to the maintenance department that something is changing and may be about to fail."

COMPUTERIZED TREND MONITORING Automated trend monitoring, which draws its origins from early-and relatively primitive-airline and military equipment, has matured considerably in the last decade with infusion of microprocessor technology. (One of the first widely used automated trend-monitoring functions was introduced in the early 1980s aboard Boeing's 757 and 767 airliners, which also brought the first "glass cockpits" to commercial aviation.) Characteristically, these devices automatically record engine exceedences and airframe systems component failures. They sample powerplant and systems parameters at predetermined intervals during flight, a process known as a "snapshot." One argument in favor of automated systems over the manual data-collection method is that it frees pilots to concentrate on their flying and eliminates errors in data recording.

Sampled data are collected in the monitoring system's computer memory and can be downloaded into some type of storage format, frequently credit-card size EPROMs (electronically programmable read-only memories). Or, standard 3.5-inch floppy disks are used for entry into office computers or modem transmission to trend houses for later analysis. Most trend monitors also are capable-either through dedicated control-display units (CDUs) or engine indication and crew-alerting systems (EICAS)-of notifying the flightcrew of inadvertent limit exceedences, component failures, or any event that could affect dispatch or safety of flight.

Trend-monitoring equipment falls into two categories: (1) units included in some upscale integrated avionics suites that are factory-installed in new aircraft by airframe manufacturers (particularly those equipped with EICAS) and (2) dedicated retrofittable devices that can be mounted in aircraft with more conventional avionics. Notably, the rotary-wing community has accomplished pioneering work in the development of compact on-board trend-monitoring systems as a means of addressing the high cost of helicopter operations.

In older aircraft, the automated units generally use the existing engine instrument transducers and temperature probes and air-data computers (ADCs) to obtain their inputs, converting analog data to a digital format. However, some manufacturers install their own digital sensors. For aircraft powered by newer turbofans equipped with full-authority digital engine controls (FADECs, or "power-by-wire"), the process of sampling performance data frequently is simplified, involving a computer-to-computer interface.

HEALTH CHECK During a typical operating cycle, data are sampled at engine start, then at predetermined intervals after the aircraft is stabilized in cruise. "Trend monitoring can be thought of as a 'health check,'" an engineer formerly engaged in the design of trend monitors said. "Typically, you're looking for a drift of performance indicative of wear.

As the engine ages, you might have to run it hotter to get the same power, and this will show up in the [collected] data. Trend data is real information that you can base your maintenance on, as opposed to arbitrary limits."

The payoff for trend monitoring is-or should be, if it's used correctly-bottom-line savings in direct operating costs. Two avenues to cost savings are immediately apparent: (1) extending inspection intervals and time between overhauls (TBOs), in cases where the engine manufacturer and FAA permit on-condition maintenance subject to trend analysis, and (2) detecting and preventing potential catastrophic failures. In other cases, fuel savings can result from revised operating procedures, since trend data interpolated into appropriate graphs or strip charts provide an intimate picture of power management.

"How much money you can save is variable, depending on your operations," said Jon Anderson, president of Turbine Trend Analysis, a trend house licensed by Pratt & Whitney Canada. "Consider this example, though," Anderson continued. "The PT6A-28 turboprop has a TBO of 3,500 hours, and the hot section is pegged at 1,250 hours. You end up doing two hot-section inspections during the TBO interval-the second being a short one. Now, if you can stretch the hot-section interval to 1,750 hours, you've eliminated one inspection at a cost of $30,000 to $40,000. I've seen some airline-operated PT6As stay on the wing for as long as 15,000 hours."

Engineers at Shadin Company of Plymouth, Minnesota, who work for this manufacturer of compact engine trend monitors, cite a helicopter operator that fields 10 AlliedSignal (formerly Lycoming) LTS101 turboshaft- powered Eurocopter BK-117s in EMS. Each is equipped with a Shadin ETM (engine trend monitor). As a result of its trend analysis program, the operator claims to have seen a 40-percent reduction in maintenance costs and fuel savings of $200 per aircraft, per month. "With that airframe/engine combination," a Shadin spokesman said, "the difference between 60- and 72-percent torque equates to 10 gallons of fuel per hour with very little useful increase in airspeed. We believe that the ETM allows closer management of the aircraft.

The future is on-condition, observed Andy Fitzgerald, vice president of maintenance of KaiserAir, Incorporated, an Oakland-based charter/management company, referring to the ultimate destiny of aviation maintenance policy. "The airlines have known this for years, and most of them won't buy an airliner unless it's equipped with trend-monitoring boxes." B/CA

URL: http:www.aviationweek.com/bca

GRAPHIC: Table, Photograph: Honeywell's Primus integrated avionics system (shown above in a Dornier 328) provides varying levels of trend monitoring and condition monitoring-from simple engine-watching to keeping an electronic finger on nearly every airframe system.

; Photograph: AlliedSignal's Multi-input Interactive Display Unit (MIDU) can be used as a maintenance terminal.

; Photograph: This Aircraft Condition Monitoring System Data Management Unit is part of AlliedSignal's MDAU.

; Photograph: Collins' Pro Line 4 maintenance menu (above), and engine exceedence (top right) and avionics trend-monitoring displays

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PR Newswire

February 11, 2001, Sunday

SECTION: FINANCIAL NEWS

DISTRIBUTION: TO BUSINESS AND TECHNOLOGY EDITORS

LENGTH: 660 words

HEADLINE: BFGoodrich Health and Usage Management System Selected by Sikorsky **Aircraft** As Standard Equipment on S-92 Helicopter

DATELINE: CHARLOTTE, N.C., Feb. 11

BODY:

Sikorsky **Aircraft** Corporation (NYSE: UTX) has selected The BFGoodrich Company's (NYSE: GR) Integrated Mechanical Diagnostics-Health and Usage Management System (IMD-HUMS) for all S-92 helicopters. It also includes provisions for incorporating IMD-HUMS technology on future production S-76 **aircraft** and S-70 and S-80 **aircraft** sold internationally. First production deliveries will be made to Sikorsky in 2001. The 10-year forecast for the **aircraft** deliveries ranges between 244-412 **aircraft.**

(Photo: http://www.newscom.com/cgi-bin/prnh/20000314/CHTU013-a)

"This is the first major step in Sikorsky's Integrated Customer Support System, which provides the **aircraft,** operator, factory and suppliers with the real time data needed to provide economical 21st Century support and safety," said Sikorsky President Dean Borgman. "We're confident that this will translate to significant savings both in time and money for our customers."

The IMD-HUMS, produced by BFGoodrich's Fuel and Utility Systems division, includes an on-board component which gathers and processes data on **aircraft** usage and the condition of engine and drive train components. The information from the **on-board** system can be displayed to the crew and is routinely transferred to a ground-based **computer,** which generates summaries of operations, forecasts **maintenance** requirements, and supports rapid **troubleshooting.**

"The incorporation of IMD-HUMS on all production **aircraft** of a type is a major milestone in the evolution of HUMS technology as an integral element in improving the support of operators and productivity of helicopters," said Harry Arnold, President of the BFGoodrich's Fuel and Utility Systems division.

"Sikorsky **Aircraft** is the first U.S. manufacturer to take this step," he continued.

The BFGoodrich IMD-HUMS is also being deployed by the U.S. Marine Corps on the Sikorsky CH-53E Super Stallion and by the U.S. Navy on the Sikorsky SH-60 Seahawk family. It is currently being evaluated for deployment on the U.S. Army's Sikorsky Black Hawk family.

BFGoodrich has already delivered an S-92 integration unit and will be supporting the development and certification flight tests that are expected to culminate in a Type Certificate for the **aircraft** and a Supplemental Type Certificate for the IMD-HUMS in early 2002. The IMD-HUMS is being certified in accordance with the FAA Advisory Circular on HUMS, AC 27-1 and AC 29-2. The IMD-HUMS will be the first HUMS system to be certified in accordance with these new standards.

With 2000 sales of $4.4 billion, The BFGoodrich Company (NYSE: GR) is a leading worldwide supplier of aerospace components, systems and services, as well as sealing and compressor systems and other engineered industrial products. BFGoodrich is included on Forbes magazine's Platinum List of America's best big companies and is ranked by Fortune magazine as one of the most admired aerospace companies. The company has its headquarters in Charlotte, North Carolina, and employs 24,000 people worldwide. For more information, please visit our website at www.bfgoodrich.com.

Fuel and Utility Systems, a division of BFGoodrich Aerospace, designs and manufactures fuel management systems, proximity warning systems, fire protection systems, health management systems, and electromechanical actuators for a wide variety of commercial and military **aircraft** and missiles. For more information, please visit our website at www.bfg-fus.com.

Sikorsky, with headquarters in Stratford, CT, develops, manufactures and supports a family of commercial and military helicopters. Sales in the year ending 2000 were $1.8 billion.

PR NEWSWIRE

August 18, 1999

LENGTH: 271 words

HEADLINE: TECSTAR Demo Systems Division Awarded Multi-Year Supply Contract Extension With Boeing

BODY:

MOORPARK, Calif., Aug. 18 /PRNewswire/ -- TECSTAR Demo Systems Division has signed a multi-year contract extension through 2006 with The Boeing Company, Seattle, Washington. Under the contract, TECSTAR will continue to provide portable maintenance access terminals (PMAT) for the Boeing 777 airplane.

The PMAT serves as a high-speed **maintenance computer** installed on the Boeing 777 to provide maintenance workers access to the **onboard** maintenance system. **Fault** reports and bus traffic from over 80 avionics systems are accessible from the PMAT. It also loads operational programs and databases.

The PMAT is offered with a mass memory containing the operational programs for all avionics systems. Digital maintenance manuals can also be installed on a PMAT with mass memory. In addition, TECSTAR will continue to provide all spares and repairs sales directly to the airlines and avionics suppliers.

TECSTAR products include critical avionics equipment for airborne server applications, **maintenance computers,** and airborne data loaders; motion control equipment for both satellites and **aircraft,** and advanced solar power technology in spacecraft solar panels and arrays. TECSTAR Inc. was founded in 1954 as the country's first supplier of silicon space solar cells. Today, the privately held company is the first to manufacture and fly triple junction Cascade(R) cells and panels in space. TECSTAR employs 650 people with sales of approximately $120 million, and is ISO 9001 certified.

/CONTACT: Cayce Blanchard, Director, Corp. Relations of TECSTAR Inc., 626-934-6504, fax 626-336-8694/ 08:30 EDT

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M2 PRESSWIRE

January 29, 1999

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HEADLINE: ROCKWELL COLLINS
Rockwell Collins Pro Line 21 avionics system selected by Bombardier Aerospace

DATELINE: CEDAR RAPIDS, Iowa

BODY:

Bombardier's all-new Continental business jet will fly with a full Collins Pro Line 21 avionics suite, the aviation industry's next-generation avionics system. This selection further strengthens the long-standing relationship between Rockwell Collins, a unit of Rockwell International Corporation (NYSE: ROK), and Bombardier Aerospace.

"Bombardier's decision represents its confidence in Collins' proven performance," said Ted Fuhrer, vice president and general manager of Rockwell Collins Business and Regional Systems. "This agreement extends our ongoing relationship with Bombardier, and is yet another example of the industry's endorsement of our Pro Line systems.

"We credit our success with the Pro Line systems to the philosophy that man-machine interface - the process of physical and mental interaction with technology- remains one of our highest priorities," he added. "A Collins Pro Line system in the flight deck offers intuitive and simple operations. Our engineers understand that the placement, format, size, texture and shape of controls and symbology can assist a crew to instinctively assess their situation."

Bombardier's Continental, unveiled at the 1998 National Business Aviation Association convention, is a super midsize business jet, measuring 86 inches wide across the cabin. The **aircraft** possesses true coast-to-coast range capability with eight passengers at Mach.80. Flight tests are scheduled to commence in mid-2001, with certification and first deliveries to take place before the end of 2002. Rockwell Collins will serve as the **aircraft's** Avionics System Integrator and is responsible for all aspects of the avionics program, from design through certification.

"Pro Line 21 is ideally matched to meet the mission requirements of Continental operators," stated Michael Graff, president, Bombardier Aerospace Business **Aircraft,** "because it provides the versatility, flexibility and ease of operation as identified by operators during our extensive research."

The Collins Pro Line 21 integrated avionics system uses proven, reliable, off-the-shelf technologies that provide increased reliability, decreased weight, ease of operation, simplified access to information due to logical and intuitive formats and complete situational awareness in the flight deck.

Information is better managed due to fewer displays, which reduce visual clutter and improve data scan. The overall effect is a much cleaner, uncluttered work environment in the flight deck, and this is emphasized by the distinctive, ergonomical design of the displays and controls, which bring a fresh, contemporary appearance to the panel.

"Bombardier and Rockwell Collins matched the Pro Line 21 avionics to the mission of the **aircraft** through an intensive joint conceptual design phase," said Steve Belland, director of product management for Business and Regional Systems at Rockwell Collins. "The result provides us with a simplified cockpit layout that includes four 12-inch by 10-inch displays, consolidated control panels and a much more efficient operation."

The system also integrates a number of other advanced technologies, including Traffic Alert & Collision Avoidance System (TCAS II) and Enhanced Ground Proximity Warning System (EGPWS) as standard equipment. Advanced situational awareness is further enhanced in the avionics suite through options such as turbulence-detection weather radar and 3-D Flight Management System (FMS) navigation map presentation.

The suite is further equipped with the Collins state-of-the art Engine Indication and Crew Alerting System (EICAS) that monitors, analyzes and displays performance of **aircraft** engines and other **on-board** systems. Linkage of EICAS monitoring capabilities to the **aircraft's maintenance diagnostic computer** permits **aircraft** systems performance and **maintenance** data to be sorted, logged, and analyzed.

The outstanding performance of Collins Pro Line integrated avionics systems has already been demonstrated aboard Bombardier's Challenger 604, Learjet 60 business jets and the Canadair Regional Jet 100 and 200 airliners. It is also being incorporated into Bombardier's new 70-passenger CRJ-700 airliner. Moreover, Collins Pro Line radio sensors are offered extensively throughout the Bombardier product line. More than 220,000 Pro Line radios are in operation around the world, making it the most successful radio product line in the industry.

Rockwell Collins, with headquarters in Cedar Rapids, Iowa, designs, produces, markets and supports communication and aviation electronics for commercial, military and government customers. The business employs approximately 14,000 people worldwide.

Rockwell is a $7 billion electronic controls and communications company with global leadership market positions in industrial automation, avionics and communications, and electronic commerce. The company employs about 40,000 people at more than 450 locations in 40 countries.

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Business and Management Practices

Technical Training

January 1999

SECTION: Vol. 10, No. 1; Pg. 12-17; ISSN: 1047-8388

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HEADLINE: The Future of Maintenance Training

BYLINE: Barron, Tom

HIGHLIGHT: Maintenance training poses some challenges for industrial training organizations electronic performance support systems and intelligent tutoring systems are some of the future trends

BODY:

Several technology-delivered approaches, including simulation, portable electronic performance support systems (EPSS), are cropping up in traditionally inexcitable training programs. Maintenance training represents an increasing challenge for a number of industrial training organizations. While content-heavy material needed to train maintenance technicians grows with every new technology investment, maintenance technicians are a mobile breed hurling defiance at standard performance support approaches. Such contradicting characteristics are exactly why learning technologies are quickly making inroads in the maintenance training area. Different initiatives are being implemented in high maintenance industries, which include material handling, airlines, utilities, and manufacturing, in order to fill the gap by offering hands-on practice via simulation, or "knowledge on the go" via EPSS. In addition, at the bleeding edge are the prototype "intelligent tutoring systems" (ITS) that integrate performance support and instruction in a portable multimedia. The US military spearheads the charge toward employing learning technologies for its remote equipment maintenance efforts. However, technology-based approaches to maintenance training are also emerging in more traditional settings. For instance, a pilot project will test a suite of technologies intended to reduce maintenance and downtime costs in the US Postal Service's many sorting centers. The project will feature a new maintenance support system from Siemens ElectroCom. System Integrated Maintenance Online (SIMON) integrates a "wearable" computer with a cellular local-area network to permit both technicians and machinery to impart information with a central computer. Meanwhile, ENEL, an Italian national electric utility is doing a study of computer-based training (CBT) methods for electrical maintenance technicians. The system uses a simulation-based methodology to teach technicians vital repair strategies. Article cites other technology-based approaches to maintenance training.

Simulation, portable performance support, and prototype "intelligent tutoring systems" are just a few of the technology-delivered approaches showing up in traditionally staid maintenance training programs.

Whether it be for **aircraft** technicians or copier machinists, maintenance training represents a growing challenge for many industrial training organizations. On the one hand, content-heavy material required to train maintenance technicians grows with each new investment in technology on the other hand, maintenance technicians are by definition a mobile breed that defy standard performance support approaches.

Those contradicting characteristics are precisely why learning technologies from the modest to the futuristic are fast making inroads in the maintenance training arena. Various efforts under way in high-maintenance industries including airlines, manufacturing, material handling, and utilities seek to bridge the gap by providing hands-on practice--through simulation--or "knowledge on the go" through portable electronic performance support systems (EPSS). And at the

bleeding edge are prototype "intelligent tutoring systems" (ITS) that combine instruction and performance support in a portable multimedia system. The U.S. military is leading the charge toward using learning technologies for its far-flung equipment maintenance efforts, but technology-based approaches to maintenance training are also showing up in more conventional settings. Following is a look at several recent developments.

EPSS Goes Postal

You might not expect to glimpse the future at the nearest post office. Yet a pilot project beginning in January will test a suite of technologies aimed at cutting maintenance and downtime costs in the U.S. Postal Service's numerous sorting centers, which rely on automated machinery.

photo omitted

Just like newer office copy machines, sorting equipment has in recent years incorporated **on-board computers** that perform self-**diagnostics** and help technicians isolate **problems,** which has already cut maintenance time dramatically. Big deal, you say? The success of that seemingly staid application has lit a fire under the bottom-line-oriented Postal Service, which sees a reduction in maintenance costs and equipment downtime as vital to its future. The pilot project at its St. Petersburg, Florida, facility will demonstrate a new maintenance support system, developed by postal equipment manufacturer Siemens ElectroCom, that uses a range of technologies to provide technicians with performance support. The system combines a "wearable" computer with a cellular local-area network (LAN) to allow both technicians and machinery to share information with a central computer--including video images that can help technicians diagnose problems remotely.

"Instead of getting a call about broken equipment from someone on the floor and sending a technician with a manual and a toolbox, you're notified by the equipment itself, which is telling you what is wrong with it," explains Siemens applications engineer Dennis Mitchell. "The technician goes out knowing what the problem is, and can review the repair procedure on his wearable computer, including illustrations and video stills of various sequences. He can also reference parts information on his computer as he's servicing the equipment--and even place a part order, which is automatically forwarded from his computer over the LAN to the parts department."

The system, called System Integrated Maintenance Online (SIMON), is built around a second-generation performance support tool whose predecessor was housed in the sorting equipment's onboard **computer.** SIMON rides on the **maintenance** technician's hip inside a portable computer, developed by Interactive Solutions Inc. (ISI), that features a small LCD screen or a headset with a tiny video monitor (see sidebar, above). The system also harnesses standard data-network technologies familiar to laptop jockeys and distance learning junkies.

"The original system could diagnose about 370 fault conditions on these sorting machines and cut the amount of time technicians spent diagnosing and fixing them from 40 to 60 minutes to an average of 15 minutes," says Mitchell. But while it helped eliminate time spent by a technician paging through an 1,800-page reference manual, there was room for improvement in time lost responding to the equipment failure, he says.

"Until the maintenance technician gets there, the machine is sitting idle with an error code flashing on the screen. With SIMON, that information is relayed to a central support center, which alerts the technician, who then knows what's wrong before he even arrives." The system turns maintenance training into a briefer task of repair basics combined with instruction on using the high-tech gear, Mitchell adds.

The same approach, together with the same wearable hardware used by SIMON, is being applied in two other high-profile maintenance demonstrations--one led by a consortium funded by the U.S. Army and the other by General Motors' Cadillac division.

The Army-funded initiative seeks to develop new ways to speed maintenance training and execution in servicing an advanced generation of Army vehicles. A consortium of developers that includes the New Jersey Institute of Technology and training technology developer Raytheon Systems Company, known collectively as Operation Smart Force, is developing a voice-activated "mentoring" system housed in the Mentis wearable computer.

The system, called SmartDART, made its debut in July in a demonstration in Troy, Michigan, that was attended by both local and national media--not a typical occurrence in the ho-hum world of equipment maintenance. In the demonstration, an army technician donned the SmartDART computer and performed diagnostics and repair of a five-ton cargo truck, using voice commands to access text, schematics, animation, and video of various repair sequences that aided completion of the work.

"There's no doubt that a system like SmartDART can enhance the training received and even replace classroom training by providing service technicians with just-in-time information at the point of repair," said Elio Divito, Army project engineer. Though it has yet to conduct a formal study of the technology, "we believe there is great potential that SmartDART will improve the efficiency of technicians," Divito added.

photo omitted

And Cadillac has just completed its own pilot test of portable performance support for auto repair technicians. Three dealerships have been testing software developed by ISI, together with its Mentis system, as a replacement for the 120,000-page service manual typically used to diagnose and repair mechanical problems on Cadillac vehicles.

"The days of a technician pulling up his toolbox to the car and using only the knowledge inside his head to accomplish his task are over," said Cadillac general manager John F. Smith in announcing the demonstration last April. "There's too much to memorize, and the level of expertise required exceeds traditional training." As this article went to press, Cadillac had not yet announced the results of the pilot demonstration or whether it planned to expand testing of the system.

CBT and Simulation

The growing complexity of technology serviced by maintenance technicians is one of two drivers behind growth of maintenance-related performance support technology lowering maintenance training costs is another. While portable, voice-activated performance support systems like those using Mentis represent the sexier side of maintenance training technology, other approaches--both high- and low-tech--are also making inroads.

For instance, Italian national electric utility ENEL is pursuing research into use of computer-based training methods for electrical maintenance technicians. Unlike the performance support approach, the system employs a simulation-based methodology to teach technicians key repair techniques, relying on three-dimensional depictions of hardware presented over a Windows NT-based CBT system. A pilot demonstration of the system, which includes classroom instruction, is being conducted using an audience of 500 maintenance technicians employed by the Milan-based electrical and gas utility.

The prototype application focuses on maintenance of a common piece of electrical equipment, according to a paper on the project published by ENEL researchers Alberta Bertin and Luigi Guarrera. The prototype provides two different kinds of instructional support: guided CBT and self-training, which satisfy requirements of both new employee training and refresher training. The system employs intelligent tutoring concepts to determine the type and amount of instruction needed by individual employees.

In guided training, new employees receive instructions that guide them from an initial state of knowledge about the equipment and maintenance tasks to the target level of knowledge required for their job. "This is managed in a transparent way by the training system, which selects the next training objective to cope with in a training session and automatically plans a sequence of instructional units suitable to achieve the objective," the authors explain. "The application prototype monitors the trainee performance in order to intervene for corrective explanations, for remedial lectures, or for replanning the session in case of trainee learning impasses."

In self-training, experienced employees receive instruction based on emerging needs, setting their own training session plan that the system then executes while monitoring their performance and providing explanations.

The system allows trainees to practice maintenance skills online in two- and three-dimensional settings, "where dangerous effects of electrocution events on humans are also simulated," the developers note. While not the primary

consideration for the ENEL or other maintenance training technology initiatives, safety is an added benefit of such maintenance training CBT.

EPSS systems are also making inroads in the process industries as an alternative to classroom-based training. Industrial Training Consultants, a custom multimedia CBT developer that specializes in maintenance training, says it has seen demand for custom CBT on maintenance procedures spiral upward as facilities seek to minimize time in the classroom. More are combining traditional instruction with use of laptop-based EPSS that maintenance technicians carry on the job, says ITC president Sy-Ed Hussaini.

And mechanical simulation is increasingly employed in manufacturing settings where competition and round-the-clock production preclude instruction on manufacturing equipment.

"Companies can't afford to go out on the production floor and shut down equipment in order to train maintenance people anymore," says Tom Bussler, president of Bussler Engineering. Traditional practices such as grabbing trainees when equipment breaks down for some spur-of-the-moment instruction or holding non-production "maintenance days" including instruction have gone by the wayside in a tougher manufacturing climate, he says. The Cheboygan, Wisconsin-based company specializes in developing mechanical simulators that teach maintenance technicians the finer points of industrial machinery maintenance. Others in the growing field of mechanical simulation include Amatrol and Hane Industrial Training.

But why mechanical simulators, as opposed to a nifty CBT system? "You can do a lot of things with computers, but you reach a point where it makes sense to roll up the sleeves, get the hands dirty, and start tearing stuff apart," Bussler says, adding that the company is plotting a move into computer-based simulation. Demand for mechanical systems is enough to keep BEI busy enough for now, he adds.

Airline Approaches

Airlines employ the most elaborate maintenance training systems of any industry--due in part to the complexity of modern jet **aircraft** and to the high degree of federal regulation **aircraft** maintenance receives. However, the industry has been slower than others to migrate from its traditional classroom-based approach to use of learning technologies for maintenance training--in stark contrast to its pioneering development of simulators to train industry pilots.

That's not to say the industry is sitting on its hands, according to Carl Cox, maintenance training instructor for FlightSafetyBoeing, a training organization that was recently spun off from the **aircraft** manufacturer. As part of its sales contracts with various airlines, FlightSafetyBoeing provides maintenance training at its Seattle headquarters to the tune of some 7,000 students per year.

"It's very much a knowledge-based training environment we do get into some simulation, but primarily spend a lot of time in the classroom providing the knowledge necessary to perform troubleshooting and repair," explains Cox. That's beginning to change as new commercial **aircraft** designs rely more on interconnected computer systems, which call for greater use of CBT and simulation-based approaches, he adds.

photo omitted

"In older **aircraft,** there's a traditional maintenance regimen that's more a system-by-system approach, which lends itself to classroom instruction," Cox says. "On new **aircraft** like the Boeing 777, the systems are much more interconnected and have more built-in diagnostic tools that lend themselves better to CBT and simulation."

Although the six-to-eight week regimen used by FlightSafetyBoeing to train maintenance technicians is mostly instructor-led, classrooms are equipped with computers and overhead projectors that students turn to for dynamic illustrations of various systems. And a simulator is used to provide hands-on practice in critical maintenance procedures.

One major change under way in its management of maintenance training is the way FlightSafetyBoeing keeps up with changing **aircraft** maintenance requirements. What used to entail periodic line-by-line comparisons between training materials and **aircraft** maintenance manuals is now accomplished through electronic means. "We've integrated our

training manual with the maintenance manual so that what a student learns in our manual is the same thing he'll see out in the field," says Cox.

A larger migration to technology-delivered approaches is under way--albeit gradually--in response to growing demand from Boeing's customers. Boeing recently developed a CD-ROM-based version of its massive maintenance manual in the form of a hypertext-referenced online manual. Meanwhile, FlightSafetyBoeing is exploring distance learning options to provide maintenance classes to airline technicians. "And we're also beginning to think about delivering modules of learning to customers over the Web on an as-needed basis," says Cox.

FlightSafetyBoeing's incremental approach to incorporating learning technologies into its maintenance training regimen may be more typical of industry efforts than high-profile experiments such as the U.S. Army's. While no one is saying that technology-delivered performance support will completely supplant classroom instruction, few doubt that maintenance training will be a grateful beneficiary of EPSS, CBT, and simulation technology--especially as industrial maintenance itself becomes more technologically complex.

"The advances in learning technologies are practically leapfrogging each other," says Gary Bosworth, program manager for the SmartDART project with the U.S. Army Tank Automotive and Armament Command. "And unlike a few years ago, those technologies are becoming robust at a much quicker pace."

Judging by the latest crop of pilot projects in the maintenance training arena, the next few years should prove interesting indeed.

Tom Barron is editor of Technical Training.

Wearable Computer Adds New "P" to EPSS

Portable--the key ingredient in a performance support system for maintenance technicians.

Until recently, portability in maintenance-related EPSS was defined by a laptop **computer,** which has housed **maintenance** EPSS systems for Navy maintenance technicians, industrial plant technicians, and others. But in many maintenance environments, laptops are a misfit--and not merely because there isn't a lap available for them to perch on.

"It's a real dusty environment--not the kind of place you'd want to use a keyboard interface," says Siemens engineer Dennis Mitchell of postal sorting centers that rely on the company's sorting equipment. Siemens began exploring development of wearable computers as far back as 1990 for use in postal equipment maintenance EPSS, but was unimpressed until the 1997 debut of a system developed by Interactive Solutions Inc., a subsidiary of Sarasota, Florida-based Teltronics.

The system, called Mentis, is the hardware behind several current mobile EPSS applications. Its components include a Pentium MMX-based CPU measuring five by seven inches that is worn around the waist and the choice of a headset-mounted color LCD display, a mountable flat-panel display, or a touch-sensitive screen display. The system also features a voice-command interface built around an AT&T voice recognition engine.

photo omitted

"The system provides voice control of Windows-based applications as well as natural speech dictation," explains Rick Roth, director of operations for ISI. In applications such as the Cadillac demonstration project, an EPSS developed by Cadillac is poured into the computer's 2.1 gigabyte hard drive, and the ISI voice editor is then customized to provide voice-activated navigation of the system, Roth says. A separate software product is also available to develop multimedia applications using the system.

Because it is Windows-based, the Mentis system will run the same multimedia CBT developed for desktop systems, including 3D graphics, animated sequences, and CD-quality stereo sound, ISI says. It also features the same connectivity of a standard desktop PC, including I/O ports, mouse and keyboard ports, a bay to accommodate CD-ROM or DVD drives, and room for two PC cards.

The system, which was certified by the FCC last April for meeting radiated and electromagnetic interference requirements, is the first wearable system to be marketed commercially. "We hope to keep it that way," Roth quips.

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December 4, 1995

SECTION: FORBES ASAP; Pg. 100

LENGTH: 1927 words

HEADLINE: Digital Air

BYLINE: BY UMBERTO TOSI

HIGHLIGHT: Commercial **aircraft** are fast becoming flying computer systems. Their downlinked bitstreams can be critical to high profits and happy landings.

BODY:

FRANK THAXTER, a soft-spoken man with graying hair, swivels between two large computer screens in front of him. He is casually dressed, as are the other people in the large, computer-crammed room in United Airlines' sprawling Pacific maintenance headquarters at San Francisco International Airport (SFO). Behind partitions to his right, a ground controller monitors several flights in progress and gazes at another, larger bank of computer screens, occasionally talking to flight crews by radio.

Thaxter, UAL Corp.'s fleet manager for DC-10s and Boeing 777s, doesn't talk to the pilots. He just watches. One screen in front of him displays up to eight windows he can enlarge or overlay at a keystroke. Using a worldwide network of **maintenance**-center **computers** plugged into his station, he's ready to intercept problems anywhere they crop up.

As passengers on a Boeing 777 watch the inflight movie and sip chardonnay 35,000 feet over Newfoundland, United's SFO computers are recording every critical function of the airplane, crunching numbers, analyzing and displaying readouts. On a constant, real-time basis, Thaxter and the other support people at the workstations around him get information they need to know if and when tactical support may be required. Maintenance, once the grimy workhorse of the airlines, has taken on a military precision and global scope unprecedented even in the technologically complex world of commercial aviation.

Although computers are old news in aviation, the new capabilities of Thaxter's array -- called an **aircraft** maintenance information system (AMIS) -- are of a vastly higher order. AMIS produces a symphony of electronic information that keeps **planes** shipshape and flying more cost-effectively than ever before. In the second half of the '90s, the use of these systems will determine in large part which airlines prevail and which fail.

Once-mute jetliners now tell more about themselves than guests on Geraldo. The newest generation of commercial jet **aircraft** -- Boeing's 777 and the Airbus A320, as well as the latest corporate jets (Gulfstream, Falcon and Challenger) -- takes in data on as many as 600 parameters from tiny **onboard** computerized sensors. This is fed into a central **maintenance computer** that can analyze and report **problems** to flight crews and simultaneously downlink the information to ground stations.

Printers spew operating and maintenance information to crews in the cockpit and on the ground. Cockpit crews check diagnostics with laptop computers. Ground stations track performance, route parts and service crews where needed, and perform maintenance trend analyses that save millions of dollars in labor and parts inventory costs.

Most important, by constantly monitoring **aircraft,** a tech-savvy airline staff minimizes the need for expensive, unscheduled service stops and groundings. For the passenger, the payoff is on-time performance. For the airlines, locked in titanic competition, the bottom line is the bottom line. Says James Bennett, of Aviation Methods, a commercial **aircraft** management and consulting firm based in San Francisco, "These systems offer major cost-saving potential to operators."

Jetliners, with their redundant systems, could be operated safely without any of today's computerized self-diagnostic systems, says David E. Jones, a UAL engineering manager. "But, because **planes** are so complex, we could expect a lot of downtime while we made unscheduled repairs -- costly groundings, substitution of flights. We just couldn't compete in today's commercial air market."

Today's 777-generation **planes** allow the central **maintenance computer** to report the precise nature of a problem both to the crew and to ground maintenance. Ground crews thus have several hours to marshal resources to correct the problem immediately upon the **plane's** landing. "The ground crew gets a head start," says Jones. The net result: "We keep the **planes** flying."

LOREN CHARLTON, a senior staff analyst at United's maintenance systems division, credits deregulation of the airlines in the early 1980s for the improvements. The resulting intensified competition was a major incentive to expand AMIS technology. Deregulation also spurred consolidation of maintenance facilities. "United opted for a hub-and-spoke environment, rather than a dispersed system," he says. This meant centralizing maintenance -- and reducing parts inventories-to a handful of centers like United's sprawling Pacific hub at SFO. Doing this requires precise coordination of maintenance work schedules.

Timing is everything when it comes to controlling maintenance costs. Much of this timing is driven by the FAA. There are three categories of maintenance problems on airliners. Category No. 1 must be corrected upon landing if the **plane** is airborne, or before takeoff if it's on the ground. This would include any problem that could lead to engine failure.

Category No. 2 problems are less vital; the FAA allows the airlines to put off fixing them for prescribed time periods. The **plane** can stay in service, using its multiple redundancy back-up systems to cover the problem until it can be fixed at the next major service stop.

Category No. 3 comprises low-level maintenance problems that can be important in customer perception but are discretionary -- a broken coffeemaker, for example.

The latest AMIS systems track all three categories. "A real revolution," says United Fleet Manager Thaxter.

The cost of setting up systems like AMIS can be high. United recently installed a client/server system costing around $10 million to replace its former system, which depended on mainframe parts and inventory. The new sys tem, using Series 800 Hewlett-Packard servers, plus 900 workstations (mostly Apple Macintoshes), plugs into in-flight **aircraft** performance transmission systems. This setup will save UAL as much as $200 million a year, according to John Curphey, the project's manager.

United hasn't always been a leader in the in-flight monitoring revolution. But while competitors -- Delta, USAir and others -- downsize, "UAL is spending substantially more capital" on such systems, says Michael K. Lowry, president of AirWatch Report, a leading airline credit analysis firm in Lake Oswego, Ore. Lowry says UAL is bankrolling the new technology with capital amassed through the savings achieved by the employee buyout last year.

Lowry subscribes to the airlines' current credo: Shaving maintenance costs is increasingly crucial. "Maintenance materials and equipment account for 12% to 15% of airline operating expenses," he points out, with maintenance labor costs adding another 5% to 7%. This doesn't include operating costs incurred from maintenance-related schedule disruptions. By delivering more timely information, the new selfdiagnostic **aircraft**-maintenance systems help cut down on all three expense areas: reducing material needs and parts inventory costs cutting down labor time and preventing unscheduled groundings.

American Airlines, an early adapter of information technology, still leads in overall systems assets. But, says Lowry, "United isn't far behind in the ability to innovate, manage and control information." That, he adds, is the name of the game in the airline industry. UAL now spends $1.7 billion annually on maintenance and spare parts inventories for its 550 **aircraft.**

But U.S. carriers are playing catchup. More than a score of foreign airlines have implemented in-flight data evaluation over the past 10 years. Japan Airlines began doing it 20 years ago and today has one of the world's most advanced programs. British Airways was another leader. These two airlines used their monitoring systems to evaluate pilot as well as **aircraft** performance, with information fed back into pilot training procedures.

First-generation monitoring systems, such as those in the DC-10, suffered from many glitches. Second-generation systems, such as those in the Boeing 767 and 747-400, worked much better, although the rap on them is that they produce too many nuisance messages. For example, a crew member might inadvertently flip a circuit breaker during a routine procedure and the **computer** would report this as a fault requiring **maintenance.** "After so many false messages, mechanics lost faith in the 747-400's **computer maintenance** system," says David Jones.

Now generation three dawns with the Boeing 777, which has dozens of onboard compute?s to process and transmit critical information.

In building the 777, Boeing engineers and designers took user enhancements into account, incorporating off-the-shelf aerospace computer systems. With its latest generation of self-diagnostics, Boeing was able to eliminate nuisance-message and compatibility problems. Boeing 777 engineers consulted United and other airline maintenance people, according to Stan Lefever, Boeing's chief of avionics requirements and a leader of the 777 engineering team.

"They learned their lesson," notes Jones, "and put together a much more robust, sophisticated system."

FEW TECHNOLOGICAL advances come without a downside. The increasing sophistication of in-flight computing and transmission on commercial **aircraft** isn't seen by everyone as a panacea. Airline pilots, particularly in the U.S. and Britain, have voiced concerns through their unions about the Big Brother aspect of such systems. Government guidelines in both countries offer some protection against pilots being singled out through the monitoring of in-flight data, which often can be ambiguous when it comes to evaluating pilot judgments. Airline lawyers are also wary of in-flight performance data linked specifically to crews. Such data can become interpretive nightmares during discovery procedures in a lawsuit.

"There's no doubt that the sophisticated computer systems on this new generation of **aircraft** could be used to monitor and second-guess the performance of a particular pilot," says UAL staff analyst Charlton. "The airline could monitor fuel consumption and criticize a pilot for flying in a way that burns more fuel than some other way."

As United prepared to implement the 777 systems last summer, Charlton led a campaign to allay flight crews' suspicion. He conducted extensive briefing meetings with air and ground crews on the new systems and how UAL would implement them. He also made presentations to management and union representatives.

Another challenge: making sure computer-generated information neither overwhelms employees nor makes them complacent. Finally, it is a full-time quest just to determine the most cost-effective ways to use the new information.

"We're just beginning to learn how to take full advantage of the features on the Triple Seven," says Marilyn Hardy, engineering coordinator for the 777 engines. The computer-generated information produced from these **planes** is not limited to mechanical or electronic functioning but includes customer amenities as well. Onboard systems routinely report the water level in a **plane's** toilet tanks, the functioning of cabin sound and environmental systems, burned-out passenger lights and other noncritical but customer-vital information. Someday, a late **plane** may tell your alarm clock you can sleep an hour longer.

Keeping pace with this technology will require continual adjustments on the part of airline crews, as well as adaptations in systems and methods. Says Charlton, "The potential benefit of these new systems is almost unlimited, and we're only in the early stages of applying them."

GRAPHIC: Photographs 1 through 4, no caption, United Airlines

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September, 1994

SECTION: No. 582, Vol. 49; Pg. 57; ISSN: 0983-1592

IAC-ACC-NO: 16110787

LENGTH: 1359 words

HEADLINE: Radio days; upgrading airlines' communications equipment

BYLINE: Fitzsimons, Bernard

BODY:

LONDON: UPGRADING CURRENT COMMUNICATIONS EQUIPMENT IS GOING TO COST THE AIRLINE A PACKET. WHAT ARE THE BENEFITS?

Radios are apparently mundane items in an avionics firmament populated by such exotica as head-up-displays, enhanced vision systems and colour weather radars with windshear prediction. But it would be hard to conceive of an air transport system without them. And they are set to be big business.

ARINC chairman and CEO Andrew Hospodor estimates that equipping 92% of the worl fleet with ATN-compatible VHF data link (VDL) will cost airlines $1.4 billion over the next 10 years. Based on a projected total fleet of 12,000 **aircraft** by 2004, made up of 6,000 new ones plus 6,000 survivors from the 10,500 in service today, the calculation assumes prices of $20,000 to upgrade current ACARS to th ARINC 622 interim standard or $100,000 to add 622-standard equipment to those without ACARS, plus a further $75,000 for the VDL upgrade. VDL installation on new **aircraft** is costed at $125,000.

PREDICT FAULTS AHEAD OF TIME

Collins, Harris, the CNI Division of Thomson-CSF and AlliedSignal are among the firms working on new VHF data radios (VDRs), which will also support digitised voice communications. Thomson CNI, which is collaborating with Siemens-Plessey' Roke Manor Research centre on solutions to the problems of frequency congestion says the problem in Europe is so acute that a direct transition to digital voice, as proposed for adoption in the USA, is not possible. Instead, the company says VDRs with a reduced channel spacing mode will be needed to reduce the current 25kHz spacing and make more channels available to accommodate the short-term demand for more voice capacity and the medium-term requirement for data communications.

For ACARS **aircraft,** including virtually all new-production widebodies, the interim upgrade is not much of a problem: as Hospodor points out, virtually any improvement in air traffic services would justify a $20,000 modification. The subsequent move to VDL radios, which are expected to be available from around 1999, will be driven by the increased efficiency of the system. Data throughput at 13 times the current ACARS rate of 2,400bit/s, or 43 times using compression techniques, should reduce transmission costs and reduce delays.

Hardware changes

But there will also have to be changes to every part of the end-to-end system hardware, which is where the air traffic service providers will have to offer some justification for the expense.

SITA, for example, will probably have to upgrade its Aircom network to meet the speed and reliability requirements of ATS messages as the result of a current audit by the UK and French authorities.

ACARS was developed initially for the most basic operational data, but has been developed to a high degree of sophistication by some operators. Air Canada, for instance, after calculating that it would be cheaper to install its own ground network than pay ARINC's message charges, developed a software package called DataPlus to control and track data link traffic between its **aircraft** and applications such as flight planning, fuel management and weather services.

One of those applications, **Aircraft** Monitor, collects, stores and analyses data on the performance of engines in flight. Air Canada has already introduced the ability to send plain English messages in addition to the fault codes generated by the central **maintenance computer,** and developed an interface with the Boeing Fault Isolation Manual. That makes detailed **troubleshooting** information available to the flight crew or ground engineers via the ACARS **terminal,** avoiding the need for an expensive **on-board** electronic library system.

Now the airline is working with Canada's National Research Council, Canadian Marconi and General Electric on the prototype of a decision support system that will combine the historical records, parts availability databases and other sources such as the troubleshooting manuals with scenarios developed on the basis of input from experienced engineers. The objective is a system that will be able not only to suggest corrective actions, taking into account the **aircraft's** destination and whether the necessary parts and people are available there, but also to predict faults ahead of time.

Some services are becoming available from the ground. The delivery of pre-departure clearances by data link is being extended in the USA and introduced in Europe, with trial deliveries under way at Paris Charles de Gaull and Frankfurt airports and implementation under discussion with the Swiss, Austrian, New Zealand. UK and Portuguese authorities.

Oceanic clearances are also being trialled on North Atlantic routes, and terminal information is available at some locations.

Butthe big gains in operating will come with automatic dependent surveillance and two-way data link communications between controllers and **aircraft** on long oceanic flights.

Boeing reports that ARINC 622-compatible ground communications facilities, whic will allow the use of 747-400s with the company's FANS 1 avionics upgrade to negotiate revised clearances on oceanic sectors, should be operational in the South Pacific by April 1995, in airspace controlled by Anchorage and New York six months later, and in the North and Central Pacific by April 1996.

India has announced plans to develop a compatible ground system, and planning for the system's migration to the rest of Asia and to Europe is under way.

Going the HF route

High-frequency data link is another matter. Spurned by the ATC authorities as a medium for automatic dependent surveillance reports because of its inability to provide instant voice fall-back in the case of an emergency, it does hold out the promise of a relatively cheap route to global data link for company operational data. Interavia (4/1993 p.57) has already highlighted the attractions of the medium, and recent findings by the UK Defence Research Agenc actually make some of its proponents' more optimistic claims seem positively conservative.

The performance of HF radio is limited by antenna size. The prototype P-3 AEW&C that Lockheed took to the Parrs air show in 1985 had a helical antenna in the tail sting that was so good the crew were able to talk to the tower at Burbank while parked on the Le Bourget ramp. But few **aircraft** have that sort of space t spare for an antenna. Bob Bagwell, who runs the DRA's HF radio research station says the alternative is to settle for moderate-rate data communications, use th existing antennas and radios with an add-on modem and let digital signal processing do the work.

WORLDWIDE CIRCUIT AVAILABILITY OF 95%

The Doppler shifts resulting from **aircraft** motion can distort the pitch of the 16 tones used in multiple-frequency shift-keying (MFSK), which has created reluctance to use the technique. Bagwell says the solution is to use Kalman filtering to correct for Doppler shift and **aircraft** manoeuvring, creating a "digital bucket" for each tone and using Doppler track filtering to track the shift in the tones.

Trials with a modem developed by the DRA and Racal have demonstrated worldwide circuit availability of 95%, enabling the UK station to communicate with **aircraft** as far afield as Australia. "We were surprised it did so well," Bagwel says. An even bigger surprise was that the plots of the output from the correction processing corresponded almost exactly, albeit with a slight time lag, to those from the inertial navigation system tracking the **aircraft's** cours and acceleration.

Rohde & Schwarz, which was formerly teamed with Teledyne Controls in a scheme t develop new HF and VHF data radios, has switched its allegiance to AlliedSignal The latter's acquisition of Sundstrand Data Control last year brought with it Sundstrand's HF activities, which included a prototype network covering the North Atlantic. Now the German and US companies are collaborating on a data module that will form the connection between AlliedSignal's ACARS equipment via the Rohde & Schwarz XK 516 D high-frequency radio to the AlliedSignal HFDatalin system.

GRAPHIC: Illustration; Chart; Graph

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November 22, 1993

SECTION: INTERNATIONAL AIR TRANSPORT; Vol. 139, No. 21; Pg. 60

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HEADLINE: BOEING 777 DESIGN TARGETS GATE MECHANIC

BYLINE: PAUL PROCTOR

DATELINE: SEATTLE

BODY:

Boeing continues to fine-tune design of its new 777 transport with a goal of reducing anticipated carrier maintenance costs and improving dispatch reliability.

The strategy is intended to increase product appeal and competitiveness through lower operating costs. Cash-strapped airlines are attacking high operating costs as cutthroat competition and fare wars lower profit margins.

A main focus of the 777 maintainability push is the gate mechanic, according to Jack Hessburg, program chief mechanic. "He's the guy who can get you high dispatch reliability," and avoid expensive gate delays or flight cancellations, Hessburg said. The emphasis "makes it easier for him to do his job."

The gate mechanic has a limited time in which he can perform necessary repairs before a flight is delayed. Southwest Airlines, for instance, is turning around its flights in as little as 20 min.

As a result, software written for the 777's **on-board maintenance** system (OMS) **computer** includes an "inbound **faults**" category. Its purpose is to quickly communicate to the gate mechanic only those system faults that affect airworthiness -- and subsequent timely dispatch.

OMS maintenance messages help determine the root cause of the fault. The OMS is designed to tell the mechanic "what it knows" rather than make arbitrary fault isolation decisions for the mechanic when an ambiguity cannot be resolved.

Extraneous maintenance data are excluded. Only information essential to fault diagnosis is displayed. Detailed engineering and maintenance management information is available through other OMS operating modules. Maintenance software engineers also worked to reduce nuisance fault messages in the 777's OMS and Engine Indication and Crew Alert System (EICAS), Hessburg said. Nuisance messages are a major cause of gate delays in current-generation transports.

SOLUTIONS INCLUDED screening out nonessential EICAS and OMS information and improving correlation of OMS fault messages to EICAS messages. Improved fault consolidation software was incorporated to minimize "cascaded" fault reports. Fault-monitoring circuit logic was upgraded, including longer notification delays where prudent. As part of this effort, OMS software and **aircraft** systems were operated under a variety of ground power conditions, Hessburg said. Power transients and interruptions are a frequent cause of nuisance faults.

All OMS communication is performed in simple English, minimizing abbreviations and contractions for mechanics who are not proficient English speakers, Hessburg said. Two on-board maintenance terminals are installed in the 777. One is in the cockpit aft of the copilot's seat, and the other is in the forward electronics compartment.

Boeing's 777 maintenance team, made up of Boeing experts as well as personnel from four launch customers, evaluated typical gate mechanic tasks for ease and speed. Part access and replacement was studied under a variety of temperature and weather conditions and during day and night operations.

Airline gate mechanics were brought in to perform troubleshooting and repair tasks on mock-up assemblies to verify procedures and ease of replacement, Hessman said. Subjects sometimes were not given repair instructions to observe how they would proceed intuitively.

Boeing also developed a comprehensive minimum equipment list (MEL) for the 777. It clearly addresses relationships between EICAS and maintenance messages.

An effective MEL is es sential to reliable airline operations, Hessburg said. It ensures transports can remain in revenue service while repairs of redundant systems are temporarily deferred.

Maintenance-related changes to 777 design included modifying the electronics rack for better access and cooling. The rotating beacon in the fuselage crown was relocated and redesigned to allow bulb changes from inside the **aircraft.** The APU battery is issued the same part number as the **aircraft** main battery to streamline inventory and allow swapping batteries if one goes bad. The 777 design team also made recommendations that streamlined overnight, shop and major maintenance work. These operations, while not as time- and departure-critical as in a scheduled environment, also reduce 777 maintenance costs, Hessburg said.

URL: http://www.aviationnow.com

GRAPHIC: Photograph, CATIA image shows a human model performing an elevator adjustment in the compartment underneath the Boeing 777 flight deck.

LOAD-DATE: November 26, 1993

Aerospace America

January, 1993

SECTION: AVIONICS; Pg. 32

LENGTH: 3116 words

HEADLINE: Finding fault with avionics

BYLINE: by Alan S. Brown, Contributing Writer

HIGHLIGHT: New design and testing approaches may increase electronics reliability by uncovering flaws before they cause failures

BODY:

ALTHOUGH avionics rank among the most durable of all **aircraft** parts, they sometimes fail. Corrosion, vibration, electrical overstress, and poor design all take their toll over time. At best, electronic and electrical failure costs commercial and military operators millions upon millions of dollars in maintenance and repair. At worst, failures spark false alarms that cause pilots to abort flights, make poor decisions, and possibly even crash.

Avionics developers have large economic and safety incentives for reducing failures. The job requires producing robust, reliable electronic components. It extends to improving materials for printed circuit board (PCB) construction and to designing more fault-tolerant systems. First of all, however, it must begin with understanding where the problems lie.

Engineers cannot even say with assurance why, when, or where electrical and electronic failures occur. In 1986, the Air Force launched its pilot Field Failure Return Program (FFRP) to study the problem and to build a database of field failures. The Navy and Army have since joined the program, which operates out of Rome Air Development Center. All three services use the database to predict failures.

"At this point," says Dan Burns, an FFRP electronics engineer, "we look at failures and tell system people they have a failure. We want to work with logistics centers to gather failure reports and look for trends. The only way we can predict failures is to develop a history [of individual examples]." Such a database would help designers to select the most durable components and designs and to schedule more cost-effectivemaintenance.

FFRP's initial results show that half of all failures result from design problems that lead to electrical overstress, says David Dylis, who managers the program through IIT Research Institute's Reliability Analysis Center at Rome. Another 35% of all "failed" conponents show no problems when retested.

Texas Instruments' Military ProductsDiv. also runs a program for testing failedcomponents. "About 50-70% of the parts we receive retest okay," says Buf Slay, manager of quality and reliability for military semiconductors. "We see mismatches in system design, incorrect application of devices. Sometimes there's a problem in power-up sequence, voltage, or pin connections. With systems growing more complex, people sometimes pull the wrong part, or they test the part wrong."

During the 1970s, Steve Sauve, now boeing Defense & Space Group's manager of military electronic products, studied electronic failures for Navy Systems Command. Seventy-five percent of defective parts showed no problems when retested. Another 20% suffered electrical or mechanical abuse during field testing procedures. Only 5% had real problems.

FFRP, Texas Instruments, and Navy Systems Command all used different protocols to collect and classify failures. It comes as no surprise, then, that their figures differ. Still, their experience in trying to classify failures suggests FFRP will not have any easy time building a reliable database.

First, field personnel do not always have the time they need to record detailed information. "Technicians get a failed box in a maintenance shop and the chief says, 'We've got to turn this around because they need the jet now,'" says Sauve. "so they troubleshoot it fast. When they isolate an area with a problem, they pull off all 10 parts and label them 'failed.'" Most of those components will show no problems when retested.

Even if technicians do isolate the offending component, retesting often reveals no problem. Wags have dubbed this "mystical parametrical drift." The problem may lie not in the component, but on the printed circuit board on which it sits. When repair people solder in a new part, they may inadvertently fix a poor solder joint. When they refit a PCB into a socket, they may tighten a loose connection or wipe off corrosion.

Some problems slip through the cracks. Dylis speculates that poor solder joints cause many good components to fail field tests. "Technicians might not even report solder problems," he explains. "Our databases track component consumption. If they repair a solder joint in the field, it might not even show up. I'm not saying that's what done, but I have no way of knowing."

FFRP faces a challenge in developing a methodology for precisely identifying all failures that tumble out of the military's cornucopia of electronic and electrical devices. But the result is worth the effort. "If you don't go through the learning curve, you're just replacing parts," says Slay.

When complete, the FFRP database will give the military an ideal tool for tracking problems that might now escape attention. Meanwhile, the avionics industry continues to look for ways to improve engineering practices and materials reliability for military and commercial devices.

Avionics developers, pushed by airframe manufacturers, have begun toplan electronic systems that find and diagnose their own internal problems. Boeing Commercial Airplane and its key contractors are developing such a fault-tolerant system, the Airplane Information management System (AIMS), for the new 777.

In the past, avionics makers took a very conservative approach to fault tolerance, says Steven Thompson, a senior staff engineer who develops AIMs and related devices for Honeywell Air Transport Systems Div. Developers, he says, put each function in its own line replaceable unit (LRU). Today, each LRU represents a single thread -- one processor, one set of memory, one set of input/output (I/O) ports. **Aircraft** makers then install redundant LRUs to ensure a fallback system in case of failure.

"When new **aircraft** enter service, the authorities establish a minimum equipment list designed to ensure adequate backup," says Thompson. "A **plane** cannot fly without that complement of equipment up and running. Traditionally, certification authorities strongly resisted allowing **planes** to operate with defective avionics."

AIMS hopes to use the greater power of more compact electronics to take a very different approach. Honeywell plans to build redundant paths and spare processors, I/O ports, and memory into each LRU.

"We plan to operate two processors in lock-step," explains Thompson. "If there is a problem, the system will know immediately that the processors disagree and reroute itself." The LRU might sample information from a different part, such as a second gyroscope or sensor, or test different combinations of processors, I/O ports, and memory banks.

As it works its way around the malfunction, the LRU pinpoints the problem. It then logs its findings to the **aircraft's** maintenance box, which communicates them to ground personnel.

That is a far cry from today's approach. "Typically," says Thompson, "technicians have only 30-40% confidence when they isolate failed components in avionics. They swap left and right, board and modules. Under pressure to take off, they replace anything. That costs money and time, and airlines have to keep lots of spares out there.

"If we can confidently tell maintenance people what is wrong, we won't see people scratching their heads and wondering whether a **plane** is ready to fly. They'll have more confidence in their decisions."

Fault-tolerant systems will not only slash maintenance costs; they will also improve reliability enough to let jets continue flying even with known failed parts. "When our fixes are only 30% correct, no one buys that," says Thompson. "But fault-tolerant systems will more confidently detect failures and provide greater redundancy."

Will regulators let **aircraft** with known malfunctions fly? Will AIMS and similar systems work with 100% confidence? No engineer can guarantee certainty. Still, Thompson insists AIMS will help airlines solve real-world problems. "They don't want a long-haul flight grounded in Hong Kong if the maintenance facility is in San Francisco."

That, at least, is the theory. But so far, self-**diagnostic** systems have proven exceptionally difficult to implement. Others have tried to use **maintenance computers** to check **on-board** electronics, but the ultrasensitive **diagnostics** always find errors. "A light goes on and the mechanics can't find anything wrong," says one aviation association manager citing an example. "When one wing lies in sunshine and the other in shade, they get two different readings." Eventually, maintenance personnel learn to filter the readings through experience.

Systems developers have also improved the reliability of their design and manufacturing operations.

Boeing's Sauve says the ability to model and simulate circuits on a computer enables him to see how electronics operate at their limit. "We can create a worst-case situation and see how if affects circuit timing and heating," he explains. "In theory, we can check out an entire circuit before we release it." Unfortunately, simulations extend only as far as circuit functionality. Sauve's staff must still analyze and test for mechanical stress by hand.

Sauve has borrowed from the Japanese, using teams to assess designs for manufacturability and assembly. "The key to a good team is to make the product support, manufacturing, design, and maintenance people peers," he says. "They all bring a lot of experience to design. The team approach, when it works well, is the most wonderful thing you'd want to see. We've had maintenance people tell designers not to use a particular part because it always causes trouble. We try to get that experience up front, before we set the design."

More controversial is Boeing's desire to change its testing methods for military electronics from conventional environmental stress screening (ESS). Companies that use ESS test every box as it comes off the production line for resistance to temperature and vibration. Boeing wants to switch to a system wherein team members test the first unit until it fails, then redesign to fix the problem so future units will not fail.

Mundane materials problems continue to bedevil, and none causes more problems than solder. Harold Frost of Dartmouth College's Thayer School of Engineering likes to point out that people have used lead alloys such as solder for 3,000 years. "Still," he says, "there's lots of heat-it-and-beat-it metallurgy out there. No one has every carefully quantified solder behavior because no one has ever needed to do it before.

"The problem is not that we cannot make strong or compliant solder joints. We can. But companies like IBM would like to know the limits of long-term reliability. It's one thing to know that thermal fatigue will cause a joint to crack, but another to predict how and when it will happen."

Several factors complicate the picture. Most metals, says Scott Schroeder, a technical specialist at Rockwell International Science Center, deform through creep or creep-fatigue over long periods. Solder deforms quickly. "Solder is already near its melting point at room temperature when compared to most structural materials," says Schroeder. "Using solder at room temperature is like using steel at 2,000 C. solder melts at 167 C, and temperatures on printed circuit boards can reach 100 C. That's high enough to recrystallize solder and change its properties."

Schroeder sees potential problems, especially with mismatched coefficients of thermal expansion (CTE). "When electronics heat up, the chip carriers expand and the PCB does not," he says. "The resulting deformation has to go somewhere, so it goes to the weak link, the solder joints that connect the electronic packaging to the circuit board."

"Producers have to meet military specifications and other requirements that don't have a solid scientific basis," says Schroeder. "People commonly test solder joints with a straddle board. They slit a PCB containing only one component

down the middle so only the component holds the board together. They fix one side of the board and move another to simulate fatigue.

"If you're developing a new design, though, there are problems with this test. Real deformation in the solder holding the chip to the board is very small. It deforms at a complex stress; strain rate determined by lots of variables, including the compliance of the solder, board, leads, and chip carrier itself. Pushing and pulling on one end provides a very far approximation of those forces."

Solder poses even greater problems as the size of the solder joints shrinks. This happened during the 1980s as integrated circuit (IC) makers switched to controlled collapse chip connection (C4) technology. In C4, IC makers vapor-deposit 100-200-micron-diam chunks of solder on the bottom of an IC die. They then turn the die upside down and place it on a chip carrier so the tiny solder balls line up with the pinout wires. When they put the chip and carrier in a furnace, the solder balls melt to form the connection.

The C4 process has grown very popularfor large ICs, because manufacturers can bond the die to pinouts anywhere on a surface rather than just around its periphery. Using C4, producers can link dies to more pinouts without an expensive, high-precision wire bonding system.

C4 presents even more of the CTE mismatch problems confronting surface mounters. "Let's say we could match the CTE of a strong silicon die and a strong ceramic package," says Frost. "When the power goes on, the die heats up first. The bigger the die, the greater the shear between opposite corners."

Since the solder joints are not as strong as the die or package, they tend to give out first. They determine how large a chip electronics makers can produce. "Producers," says Frost, "want to predict strain in solder joints so they'll know when they will fail. IBM uses very conservative designs because it cannot take advantage of increased chip density. The more it can predict solder behavior, the more it can use new technologies."

The small size of the solder balls complicates manufacture. "In the materials world," says Schroeder, "we know a lot about polycrystalline materials and grain boundary dislocation mechanisms. But when we get down to very small systems of 10 grains or even three grains, we know little about how solder recrystallizes and dislocates across grain boundaries."

Schroeder has used the latest theoretical knowledge to model solder joints. "Rockwell wants a package that will let electrical engineers design the most compact components possible," he explains. "It wants a tool that will let them plug in the design and geometry and find out how long the part will last so we don't have to keep running prototypes through a furnace to see what happens."

The search for increased reliability has also moved down to the component level. Very few chips ever corrode or break apart because of vibration. Problems crop up, they say, only when users mount chips on printed circuit boards and build larger, more complex systems.

Yet the next generation of chips poses daunting materials challenges. Chip devices (transistors and other electronics) and interconnects (the fine wires that link devices) are shrinking to widths under 1 micron. This will bring chip makers face to face with a problem they have not encountered since the early days of integrated circuits -- electromigration or, more poetically, electron wind.

Today's high current densities crate an electron wind so powerful that it can push interconnect atoms across insulating layers and into other circuits. Chip makers eliminated the problem by adding small amounts o copper to aluminum to jam up atomic migration along the grain boundaries.

"At densities used in the 1980s," says Frost, "we avoided electromigration. As we move to finer lines, we find we cannot scale down current densities [to prevent helix formation] or make them higher [to build more powerful chips]."

Frost hopes to control the problem by controlling the microstructure of interconnect crystals, which can grow larger than the interconnect lines. "The worst things that could happen is a mix of big and little grains," he notes. "The

combination of grain boundary and no boundary regions creates a flux divergence. When the electrons come screaming along, they just pile up the atoms.

"We need to increase the ratio of grain size to line width. But to create the best, most reliable microstructure, we need to go through the worst. As we increase line width, we increase the overall lifespan of the interconnect, but also the standard deviation, so the first failure comes sooner," Frost concludes.

Frost has reason for optimism. Components have not compromised reliability much in the past; solder has, however, and avionics producers have begun to tackle the problem in earnest. They have also turned to compuer models to tighten design quality and process control. The use of fault-tolerant architectures may yet help maintenance personnel isolate faults before they cause problems. A good database can provide designers with the statistical information they need to pinpoint problem areas.

Will these new designs, materials, and approaches work better over the long term? Will they resist corrosion, vibration, fatigue, creep, acoustic bombardment, and other environmental stresses better than existing systems? Probably. Perhaps the new methodologies will cut down on the 50% of all electrical and electronic failures the Field Failure Return Program attributes to electrical overstress and poor design.

Yet methods of testing parts of resistance to these mechanical forces lag far behind the complex models used to simulate electronic circuits and solder behavior.

In the end, the best way to ensure reliable operation of electronics is to design them properly. During the early '80s, the Navy developed what has since become a triservice guide to preventing an controlling avionics corrosion. No similar comprehensive guide exists for vibration or acoustic emissions.

That puts the burden on design engineers. "Where corrosion caused failures," says Eric Carlson, a researcher with Arthur D. Little, "it happened because someone designed to a specification that didn't take into account the actual environment. In some industries, experience leaves when the people change jobs. The lessons learned in the military don't move to the next project."

Avionics makers continue to create better, more reliable products. Their next challenge will be to create a system that draws on the best design information to use them more reliably in **aircraft.**

GRAPHIC: Picture 1, IBM used controlled collapse chip connection technology to create integrated circuit dies.; Picture 2, At B. F. Goodrich, an avionics manager tests a state-of-the-art digital weather radar. The unit's advanced electronics require dedicated testing equipment.; Picture 3, Time Stress Measurement Devices are used to track and log specific yet fleeting operating conditions that cause failures.; Picture 4, QuickSim II is a logic simulator designed for complex printed circuit boards. Electronics designers use software like this to find flaws in designs before they are committed to final product.; Picture 5, Conventional inertial reference systems mount three gyroscopes perpendicular to one another, and each measures rotation about one reference axis. Honeywell's fault-tolerant Air Data Inertial Reference System mounts six gyros such that each measures a fraction of the rotation about each axis. This allows system to extract multiple points of reference from each gyro, check one against the other, and correct for up to two failed gyros.

Flight International

January 22, 1992

LENGTH: 2410 words

HEADLINE: Maintaining maintenance

BODY: A major selling point for the electronic flight instrument system and fly-by-wire (FBW) is the reduced cost of maintenance. Electro- mechanical instruments devour maintenance man-hours if they are to be kept accurate, as rigging tasks do for conventional control systems. Both types of equipment are heavy compared with their digital successors. It is these characteristics which attract Hong-Kong-based intercontinental operator Cathay Pacific to **aircraft** like its ordered Airbus Industrie A330s and to the Boeing 777s which it is also considering, says the airline's engineering director Stewart John.

Digital avionics systems will serve two main roles: more effective controls and systems; and rapid acquisition of maintenance data. Meanwhile, passenger cabin avionics are developing rapidly, with additional maintenance implications which concern John with their demands.

Long-haul airlines have adapted to advanced avionics in "half-way- digital" **aircraft** like the Boeing 747-400 and McDonnell Douglas (MDC) MD-11. Now that long-haul **aircraft** with full FBW, like the A330, A340 and 777, are in prospect, the buying airlines are having to take stock of their operational and maintenance experience and learn what they can from short-haul carriers operating the FBW leader, the A320.

Is this digital high technology always worthwhile? John is quite clear, saying: "Most emphatically not." He is worried that increasing peripheral electronics (such as cabin service/entertainment electronics and passenger communications) may deflect the maintenance task from its priorities; although, like others in the Pacific region, his airline has technical staff adept at computer technology. The Chinese affinity for computers is second only to that of the Japanese, he says. Cathay makes clear that it maintains a belief in "gradualism", avoiding the cutting edge of technology introduction.

The members of the 14-strong Oriental Airlines Association already own more than one-third of the world's widebodied **aircraft.** Its technical committee pooled the region's approach to early 747-400 problems. This effort provided a major part of Boeing's database on defects and its decided priority for remedial action, given more than 130 identified problems. The learning curve was steep and the end result was more effective remedial action than would have been produced by many airlines operating non harmonised introductions into service.

John points out that Boeing with the 747-400, like MDC with the MD-11, had to design its digital cockpits and flight management systems around a basically analogue **aircraft** and balance the difficult targets of component commonality, while "...putting the flight engineer into black boxes" with a digital transplant.

Cathay found that the first six months showed many spurious or inexplicable EICAS (engine indicating and crew alerting system) "status" messages, which could disappear after a deliberate switch-off and reboot. Hardware and sensors worked well, but wiring gave problems; the twisted-pair databus was more vulnerable than screened wire to chaffing and mis-wiring.

Cathay's maintenance organisation, although now "...feeling more comfortable" with the few remaining difficulties, still does not look forward to having to disturb wires or connectors when acting on maintenance bulletins. According to John "...you may be installing another defect".

With digital avionics, a fault's symptoms are often not just the failure of one feature, as with simple electrics. "Ohm's Law does not work any more," as John puts it. "Faults are intermittent and illogical."

His deputy, Roland Fairfield, says that software fixes tend to be iterative, with problems being reduced until "...finally cornered". He explains: "You can't think a problem through when it involves software - you have just got to believe the

manual." Both agree, however, that the 747-400 **on-b ard** central **maintenance computer** has diagnosed **problems** well.

MAINTENANCE RESOURCES

John's level of concern about maintenance resources is accentuated by the fact that FBW is coming earlier than expected to Cathay and to its Swire-owned sibling, the Hong Kong **Aircraft** Engineering Company (HAECO). Hong Kong-based charter (and, progressively, regional scheduled) carrier Dragonair, in which the Swire Group has a 46% share, is replacing its five 737s with A320s leased through International Lease Finance. The first delivery is due in January 1993. Engineering liaison with Airbus had not originally been planned until 1993, for A330s due in January 1995. There is now only one year to get familiar with Airbus and FBW.

The earlier contact will help Cathay adapt to Airbus engineer training, product support, manuals and - not least - to a metric culture. The A320 is well-established on the learning curve, so sparing many FBW teething problems. John observes, however, that maintenance read-across to the A330 is not as great as cockpit and operational similarities might imply.

Maintenance engineering's primary task is to keep the **aircraft** serviceable. "You risk unnecessarily loading the hangar with special devices for secondary avionics - working in parallel with oil, corrosion and ageing structure. It could get out of control," says John. He underlines how the new US Federal Aviation Administration criteria for maintaining ageing **aircraft** had seemed rushed and illogical from the point of view of airlines with existing programmes. Unless credit for past work is given, he insists, hangar resources - even world capacity -for heavy work would be stretched.

A carefully prepared minimum equipment list (MEL) is vital commercially, John points out, because, with modern avionics, interactions between systems can be subtle. A complex MEL reduces departure reliability. If the hardware solutions available continue to diminish, engineering prospects for the length of the MEL are, in John's view, "...very frightening", while flight operations director Mike Hardy sees it as "uncharted territory" for his crews.

BURIED IN SOFTWARE

John worries about the possibility of more functions being more buried in software than is necessary. He would like future avionics systems design to pay more attention to avoiding "invisibility" - the situation where a core failure cannot be identified immediately. He insists that corrective action on existing digital systems has to be "...blessed by the holy water of advice from base". Otherwise it is "...hands off and no circuit-breaker tripping, especially in flight, if you don't know what the hell it will do". He is wary, however, of the Airbus idea of siting most circuit-breakers below floor, away from crew access.

John is optimistic on FBW and keen about many avionics in prospect, but critical of some regulatory requirements - especially for retrofit. A long-time proponent of the ground proximity warning system, of communications links like the **aircraft** communications addressing and reporting systems (ACARS), and of satellite navigation/air traffic control systems such as the Global Positioning System (GPS)/Automatic Dependent Surveillance (ADS), he deplores US pressure for TCAS II (traffic alert and collision avoidance system) installation, at $300,000 an **aircraft.**

In an off-duty moment, John has been heard to refer to TCAS as a "typical congressional assinine suggestion", its rate of introduction having been accelerated by Congress beyond technical advice.

Mandatory windshear warning and "premature" moves to such equipment as the microwave landing system (MLS) are making the fuselage "...more a support for aerials and the like". John makes it clear that he is keen to take advantage of technology which he believes makes for an improvement in operations, saying: "We are prepared, too, to wait on elaborate equipment, with a potentially useful role and wide ranging capabilities, such as the electronic library system."

Cathay's 747-400s come ready for Mode S secondary surveillance radar and TCAS, but the airline does not intend to retrofit its TriStars, or 747-200s and -300s, which are destined for regional routes. The local regulatory authorities are watching the TCAS false-warning rate and the possibility of a need for further modifications.

Mike Hardy wants ADS for higher air traffic capacity on the Pacific. "We need reduced separation. The Vancouver-Hong Kong route has grown by 120nm [220km] on average since we started it; we can't get the short tracks," he says.

Cathay's Pacific routes would involve only a 120min diversion, but twin- engined airliners on the Pacific route have never been contemplated, says Hardy, and are unlikely with present routes and loads.

The low data-rate ACARS datalink is already proving itself, in free text exchanges between base and -400 crews. The 747-200 and -300 will be fitted with direct downlink VHF ACARS only; the -400 is fitted for satellite-link ACARS as well.

High-frequency radio (HF) ACARS is proposed by Sundstrand, with the performance of low-rate satellite-link ACARS. Correction algorithms for error and fade should be no more difficult than those for existing satellite communications. Cathay says it might be interested in conducting a trial.

Direct contact from the cockpit on the ground overseas brings in the immediate technical resources available at base. With two-man crews (no flight engineer), the number of calls to maintenance before departure from home base Hong Kong has also risen. The main ACARS payoff so far has been rapid replanning on very long routes, so avoiding fuel diversions. If a Los Angeles-Hong Kong flight is held at lower altitude - over Taiwan, for example - a new flightplan can be uplinked quickly from operations to the cockpit.

The latest forecasts and alternate airport weather can be relayed in minutes through the links with the Societe Internationale de Telecommunications Aeronautique network and crews ask for these three or four times during each flight.

EARLY PROBLEMS

The automatic transmission of maintenance parameters had a poor start on the -400, says Cathay, but since modifications, performance has improved. The **aircraft** central maintenance system was prone to ACARS interface problems in its early days. It is due for another system software update and some redesign in the first quarter of 1992.

Cathay has limited its use of ACARS for transmitting real-time maintenance data until it has more experience, but it is anxious to realise the potential; the amount of paperwork, even on -400 equipment, is still much too high.

So far, defect processing has centred on monitoring the Rolls-Royce engines, where parameter excursions are flagged. The software uses an existing IBM mainframe and data is downloaded at arrival an engineering personal computer-based station.

Cathay's RB.211 engines are still not fitted with full FADEC (full authority digital engine control), which is due with the eventual "package three" installation. Fairfield sees FADEC as a good means of control reliability; in spite of years of experience, the fluidic controllers are always exposed to bleed air contamination.

Airframe performance and systems monitoring may remain a bottleneck until the **aircraft** ACARS has been worked up to full performance, the ground interrogation structure is fully in place and data form and rate decided.

Satellite link at high data rate is not a Cathay priority. Worldwide passenger telephones, which would demand high rate, may offer little return for the capital and maintenance costs of multiple channels. Use of overland VHF telephones, in the USA is said to be falling, as the $10/min cost sinks in. Japan Air Lines is experimenting carefully with a satellite link telephone installation in only one of its oceanic fleet to find out whether its passengers are really prepared to pay even the charge of about $13/min, which is less than cost.

Cathay is content for other airlines to make the running in cabin telephones and datalinks for passenger hotel and car booking, while the maintenance implications are studied. It is ready to react and install such equipment rapidly if it proves durably attractive to passengers. Singapore Airlines is the only carrier so far with a finalised long- range fleet satellite-link telephone installation plan. A single satellite-link voice channel in the cockpit, for use where symptoms, malfunctions and action required can be better described verbally, is important with a two-pilot crew, John believes. This does not require the full high data-rate capability.

Meanwhile, in tomorrow's cabin, particularly in first and business class, keeping complex or vulnerable entertainment modules serviceable will be time consuming, John predicts confidently. Cathay is to fit, starting in March, an economic and simple extension of the existing video projection facilities in the three cabin zones - at less than a fifth of the cost of one of the more advanced products becoming available on the market. Hard-wired coaxial cables will carry, via interface boxes, all three movies to 15cm liquid-crystal-display screens at first-class seats. This will be done within existing certification, John notes.

A fourth channel will be the popular "Airshow" (moving route maps and flight data). Its aural channel will carry the BBC world service, which has been received well in trials from fin-top aerials; all 747s will be equipped by March.

NEW TWINS

Cathay has not operated a twin since its early years, but as well as the ordered A330 it is now looking seriously at the 777. One quality of the Boeing FBW, in John's view, is that it can be disconnected completely. Even if all computation is lost, the basic system, controlling in all axes, is still adequate for "get you home" control standards. The ARINC 629 busbar system has matured for many years. Since the 7J7 (which was replaced by the 777) studies, a Boeing team has continued its development, and airlines such as Cathay have been kept in touch.

What of the distant future - with artificial intelligence and expert systems? "The computerisation of accumulated engineering wisdom might bring its own software problems," says Fairfield. "We will always prefer to be in the second row [regarding equipment introduction]. Apart from caution, we are a smallish airline driven by ambitious utilisation. To sustain our financial track record we cannot live with unreliability."

GRAPHIC: Photo

Flight International

July 24, 1991

LENGTH: 1293 words

HEADLINE: Towards the paperless cockpit

BODY: United Airlines' imminent selection of a supplier for the electronic library system (ELS) to be installed in its Boeing 777s will be a significant step towards a revolution in flightdeck information handling and airline operations management. On delivery of the first United 777 in 1995 the first paperless cockpit will have arrived.

ELS, being developed by Honeywell, Bendix, Rockwell Collins, Sextant Avionique and Smiths Industries (the front-runner is reckoned to be Rockwell Collins), is intended to replace the volumes of charts, logbooks and manuals stored in the cockpit of every civil airliner, and carried in every pilot's flightbag.

Although it will be seen first on United's 777s, ELS will be standard on future generations of Airbus and McDonnell Douglas **aircraft,** while United intends to retrofit ELS into every **aircraft** in its fleet after 1995. Other operators, including American Airlines, British Airways, Japan Airlines and All Nippon Airways, are considering retrofits.

Although ELS technology itself is impressive - providing a storage capacity equal to around 60,000 pages in hard-copy manuals - the real challenge in developing the system to its full potential lies elsewhere. In order to gain widespread airline acceptance of the concept, the suppliers, operators and airworthiness authorities will have to agree first on a common standard to format and integrate the necessary data, and then establish an infrastructure capable of supporting the massive flow of information involved.

Collins senior marketing manager Jim Kempema says: "Electronic data is going to be a way of life, but it is going to have to be done in a manner which is adaptable to airline operations. When all the subsystems involved are considered - dispatch, maintenance, cabins, and so on - getting all of these people to talk to each other is going to be a major undertaking. I don't know of any system like this with a similar magnitude of impact, not even adding glass cockpit displays, because that didn't affect the operations of the airlines."

LINE-REPLACEABLE MODULES

ELS is built around a central cabinet housed in the **aircraft's** avionics bay, and connected to the cockpit displays, access terminals and other **aircraft** systems via fibre-optic links. The cabinet contains a number of line replaceable modules (LRMs) which include a power module, processor input/output module and both magnetic mass-memory and magneto- optic mass memory LRMs.

The system will be developed using a building-block approach, adding functions and LRMs as the memory capacity becomes available and airline demand for stored information grows. Collins is evaluating three discrete channels on its ELS - one for flight deck and maintenance operations, one for the cabin, and one for growth.

In its current configuration, the Collins system will provide the flightdeck crew with all **aircraft** performance data, checklists, flight manuals, taxi diagrams, departure/approach plates and en-route charts. Pilots will also be able to access the flight and maintenance logs.

The ELS will be integrated with other on-board systems - in the 777's case, the Honeywell-developed aeroplane information management system which integrates all communications and navigation functions. This in itself creates an engineering challenge for competitive suppliers, but means that when a system malfunction is annunciated on the electronic flight instrument display, for example, the ELS will display the relevant page from the quick-reference handbook automatically, allowing the pilots to view the correct procedure at a glance without paging through a manual.

Once addressed, evidence of the failure would be stored in the memory of the onboard **maintenance computer.** The information would then either be downloaded on the ground through the ELS, or downlinked via the **aircraft** condition and reporting system or satellite datalink for remedial action on arrival.

DISPATCH DISKS

Before departure, crews would be provided with updated dispatch information including en-route weather and NOTAMS (current operational information), flight manifest, weight and balance data and take-off and landing performance data. This information would probably be provided on a floppy disk and downloaded into a smaller memory bank in the cockpit, with a capacity in the region of 400 megabytes.

Collins is also investigating a concept known as "gatelink", which would download the data via an interface at the jetbridge. This could be used to update the **aircraft's** navigation databases, along with the other dispatch information, and also to download all maintenance data from the **aircraft** on arrival.

The system would store all the maintenance logs for the maintenance crew, (with entries via the cockpit access terminal), minimum equipment lists, **fault** isolation and reporting manuals and equipment location information. Interrogation of the **onboard maintenance computer** (OMC) and dispatch release would be accomplished through the ELS.

In the cabin, the ELS would store check lists, special passenger needs, cabin maintenance log entries, flight schedules, reservations and catering and beverage inventories. It could also be used for functions such as ordering duty free sales in flight for collection on the ground, thereby reducing the weight and safety hazard of dozens of bottles of spirits on board the **aircraft.** Kempema cautions, however: "The major obstacle is having the infrastructure set up so that it all works". Indeed, establishing the infrastructure to support ELS will be the main concern among the airlines, suppliers and various industry watchdog committees. With so much data required, there will be no room for a dual US/European standard.

Because airlines will be reluctant to devote manpower or financial resources to identifying and coding source data for their own onboard ELS, it is likely that the suppliers will become responsible for cooperating on the establishment of a common-ground database, in consultation with the airlines through bodies like ARINC, the US Air Transport Association, and the Society of Automotive Engineers, which helps set flightdeck engineering standards.

Kempema says: "We are going to have to start working with the airlines to create some new standards, because until now, only the paper standards have been established". This would involve identifying what data is required, converting both non-digital and digital data into a standard digital format, ensuring the integrity of the information, and updating it where necessary. There would also have to be a common method of distribution, both to the airlines in physical (ie, floppy disk) form and radio and satellite uplinks to **aircraft** in flight.

If a common-ground database was established, NOTAMS, navigation database updates and airworthiness directives, for example, could be sent to one central point and distributed in common format. Maintenance actions specific to individual **aircraft** by tail number could also be distributed in this way, while the maintenance histories of individual **aircraft** could be stored and updated at a central point by downlinking information from the OMC, if airlines were willing to co-operate. This would allow manufacturers to track their fleets with greater accuracy.

Kempema says: "The challenge when setting the standard will be to keep it generic. What in truth is going to happen, as it did with FMS, is that the first supplier will set a pseudo-standard. If they do it right, they will adjust it to the users' needs and that will ensure that most users will adopt it. It's going to be a key responsibility to get the airlines together and adopt a standard which is very general, and which everyone can work with".

GRAPHIC: Diagram

Aviation Week & Space Technology

March 4, 1991

SECTION: HEADLINE NEWS; Vol. 134, No. 9; Pg. 67

LENGTH: 1167 words

HEADLINE: Air Force Completes Flight Tests Of B-1B's Defensive EW Systems

BYLINE: BRUCE D. NORDWALL

DATELINE: WASHINGTON

BODY:

The Air Force has completed flight tests of the B-1B's defensive electronic warfare system and believes that technical problems have been resolved, according to the systems program manager.

The effectiveness of AIL Systems, Inc.'s ALQ-161 will not be fully known, however, until data from more than 170 hr. of flight tests are analyzed. Air Force officials will have their first chance to examine the results about the second week in April, Col. John A. Madia, director of the B-1B Systems Program Office (SPO), said.

While the Air Force is dissecting the test data, the Institute for Defense Analysis in Washington, D. C., will be conducting a parallel analysis of the same data. Congress required the independent study when it provided funding for the latest avionics tests. Madia thinks that study will be complete by the end of May.

Even if both reports are positive, the Air Force does not have funds to add the modifications to the B-1B fleet. The service had planned to use lapsed and expired funds, known as the M account, to pay for the modifications. However the Fiscal 1991 authorization, approved last fall, expressly prohibited use of the M account for B-1B modifications (see p. 26).

Nevertheless, the ALQ-161 performed very well and appears to have met all requirements, Madia said. That judgment was based on preliminary examination of test data after each flight and a comparison of the results with laboratory tests. In fact, in one test, the system was able to detect more and weaker signals and determine bearings to the targets more accurately than required, he said.

No software modifications -- called patches -- were made during this entire test of the ALQ-161. That is a milestone, Madia said, and the first time the B-1B has completed a flight test effort without needing software patches.

Madia attributes the success of the flight program to the extensive laboratory tests that preceded it. About 10,000 hr. of tests were conducted in four hardware laboratories and one digital simulation facility. These included contractor tests, four months of government tests and an independent test by Warner-Robins Air Logistics Center, Ga.

The ALQ-161, installed in a B-1B, was subjected to 500 hr. of engineering tests in an anechoic chamber at Edwards AFB. Chamber measurements showed that the system sensitivity exceeded specifications and that all other characteristics were consistent with laboratory results, Madia said. The positive anechoic results increased Air Force confidence for the airborne stage.

The flight test program began in October, 1990, and was to have concluded in January, but engine problems that grounded the entire B-1B fleet between Dec. 19 and Feb. 6 delayed the testing (AW&ST Oct. 15, 1990, p. 50). General Electric developed an engine modification that allowed the B-1B fleet to return to normal operations (AW&ST Feb. 11, p. 24). Flight testing resumed on Feb. 6 and was completed last week.

Twenty-one sorties were devoted to combined developmental and operational testing, and two more were dedicated exclusively to initial operational test and evaluation. Although the flight effort was based at Edwards AFB, Calif., the tests also used range facilities at the Naval Weapons Center, China Lake, Calif., and Eglin AFB, Fla.

The tests did reveal two areas that still need improvements -- the **aircraft's** central integrated test system (CITS) and the **aircraft's** displays.

CITS presently has too high a false-alarm rate. The system reports intermittent conditions, including some caused by normal system operation, as failures. The solution may be as simple as changing the failure criteria to require several checks before a system is diagnosed as having a **problem,** Madia said.

The idea behind CITS was to use an **on-board computer** for **maintenance troubleshooting** and reduce the need for ground test equipment. But developing the diagnostic software is an iterative process, and the work is not finished yet.

The second problem is that emitter locations appear to jump around on the **aircraft's** displays, rather than moving smoothly. The difficulty is a mismatch between the ALQ-161 and the software controlling the display. Because the display does not update each emitter's position as often as the ALQ-161, the operator sees an annoying jump each time an emitter's position is updated.

The Air Force recognized the potential display problem in 1989, but did not have enough confidence in the ALQ-161 at that time to give Boeing a contract to fix the display software. Now that the EW system appears to be working well, a software modification is needed to harmonize the display with the EW system.

There have been other electronic warfare concerns with the B-1B in addition to the ALQ-161. Madia thinks the Air Force has resolved one of those areas -- the tail warning system (TWS). The Air Force ordered AIL Systems to stop producing the TWS in January, 1990, after finding that the system did not meet specifications in terms of false alarm rate and missile detection, particularly at low altitude, where the system "sees" a lot of ground clutter. Since that time AIL and two Air Force teams have searched for the cause of the problem, and the company believes it has found the problem.

The company found that an oscillation in an antenna filter was generating acoustic noise in the receiver. That problem has been fixed, Madia said, and the system was flown on a number of missions to gather clutter data. The clutter data were then run through a computer simulation. "System performance looked very, very good in the simulation," Madia said. The Air Force has evaluated the TWS on one mission where missiles were fired at the bomber.

For the missile flight tests, an F-16 or F-4 **aircraft** flies behind the B-1B, with the fighter pilot positioning his **aircraft** just outside the maximum missile range using a very accurate radar and computer. The test is designed to evaluate the performance of the TWS during the missile flight and before the missile starts losing energy, short of the B-1B.

Another B-1B EW area that aroused Congressional interest was the radar warning receiver. Congress directed that the Air Force do a comparative test between two radar warning receivers, Loral's ALR-56M and Dalmo Victor's ALR-62I. Madia's SPO wrote a test plan, which is being coordinated at the Strategic Air Command, Air Force Systems Command and Air Force Logistics Command. However, Madia said he has no funding to carry out the actual tests.

RWR testing could begin about three months after receipt of funding, and would take between 11 and 16 months. It would include antenna pattern work on the B-1B mockup at the Rome Air Development Center, Griffiss AFB, N.Y., and laboratory work at the Air Force EW simulator located at General Dynamics' Ft. Worth, Tex., facility. Computer simulations would then combine the antenna pattern and laboratory results to predict how the system would perform on the **aircraft.**

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The New York Times

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LENGTH: 969 words

HEADLINE: Technology;
Sensing the Presence Of Potential Problems

BYLINE: By EDMUND L. ANDREWS

BODY:

When people get bruised, cut or fatigued, their nervous systems send signals of pain and soreness that effectively warn them to address the problem before it leads to more serious damage.

Now, a small but growing group of researchers is envisioning analogous nervous systems - dubbed "smart skins" - for human-made structures: **airplanes,** bridges, long-distance pipelines and even buildings. The goal is to embed such structures with smart-skin technology: networks of fiber-optic sensors that use light pulses to measure the often invisible signs of cracking, bending, stress and overheating.

A "smart" **airplane** fuselage, for example, would detect microscopic internal cracks and relay signals to a computer that would alert pilots and ground crews. A smart bridge might produce reports on any failing girders, and pipelines would allow gas transmission companies to monitor the ground shifts caused by seasonal changes in remote Arctic regions.

"You have the opportunity to do vehicle health monitoring that you couldn't do otherwise," said Eric Udd, senior staff manager of fiber optics at McDonnell Douglas Electronic Systems Company, part of McDonnell Douglas Corporation.

Researchers also believe smart skins could improve the research on and manufacture of structural parts made with advanced composite materials. Engineers could bury sensors in experimental materials while they are being constructed, then plug the samples into signal-processing equipment to search for any internal weaknesses. As envisioned now, the sensors would consist of hair-thin optical fibers - like those now used in long-distance communications - that would relay light signals through a particular structure. If the fiber underwent some form of stress or change in temperature, the light signals would change in measurable ways. Using this principle, optical fibers could register minute changes in position, pressure, temperature, strain and vibration.

Ultimately, proponents of smart skins would string hundreds or even thousands of such sensors in complex grids covering an entire fuselage or wing. The signals from these grids would then be interpreted by computer to produce up-to-the-second portraits of the structure's health. In an even more advanced system envisioned by some aerospace engineers, **on-board computers** would identify **problems,** calculate the necessary adjustments for pilots and even carry out some corrections automatically.

But even the most enthusiastic proponents agree that smart-skin technology is still embryonic. "We are just scratching the surface," said Donald Bartlett, chief engineer for Boeing Company's two-year-old smart-skins program. Sensors are still quite crude and the development of proper signal processing systems has barely gotten under way. Prototype systems for **aircraft** are easily five to ten years away, and utilities and gas transmission companies are only beginning to express interest.

Still, the basic ideas have been demonstrated in laboratories and have attracted serious interest. All of the nation's aerospace companies have launched research efforts in the field, as have the Pentagon, the Department of Energy and

the National Aeronautics and Space Administration. Southern California Edison has decided to install a prototype smart system to monitor stress and fatigue on a steam boiler that drives its electric turbine generators.

"The proof of principle has been established," said John Kreidl, a fiber-optic consultant in Cambridge, Mass. "The issue is how badly do you want it and how much are you willing to pay for it?"

In theory, it has long been possible to build nerve-like systems using existing electronic sensors that measure strain and temperature. But electronic systems have been impractical. Because of their sensitivity to electromagnetic interference, they would require shielding and be too heavy for **aircraft.** Beyond that, copper wires have only a fraction of the data-carrying capacity of optical fibers. The new sensors can solve many of these problems. Optical fibers are excruciatingly sensitive to changes in pressure and temperature and they can relay volumes of data. And because they use light pulses rather than electrical signals, electronic interference poses no problem.

Prototype devices are making progress. At Virginia Polytechnic Institute in Blacksburg, Va., a leader in the field, researchers recently rigged a wooden model plane with sensors. In table-top tests, they were able to distinguish between signals associated with a damaged propeller, a loosened strut and simulated ice on the wings. The researchers are now building a model that would transmit signals by radio to a ground-based controller. The G2 Systems Corporation, a start-up company in Pacific Palisades, Calif., is now preparing to mount optical sensors on a boiler owned by Southern California Edison. It is also working on proposals to develop pipeline monitoring systems and is working on **aircraft** sensors for both McDonnell Douglas and the United States Air Force.

To be sure, developing smart skin's systems requires overcoming a slew of challenges. Boeing's Mr. Bartlett noted that no existing sensor is mature enough to implant in a working system. Much remains to be learned, moreover, about the best method for imbedding sensors in structural materials, as well as for stringing sensors into complex grids.

Perhaps the biggest challenge, however, is developing the computers and software that can convert blizzards of optical signals into meaningful information. That means developing standards for normal stress and vibration and for signals associated with particular problems. "It will be the middle or the end of the decade before the technology is mature enough for practical use," said Mr. Udd of McDonald Douglas.

GRAPHIC: Diagram: Fiber-optics sensors can be embedded in bridges and other structures, like water pipelines and **airplane** wings and fuselages, to continually monitor stress, strain and changes in temperature. "Smart structures" like these rely on computers to read and interpret minute color changes that occur when a beam of laser light strikes a sensor. Color changes signal alterations in the condition of the structure in locations that are difficult to inspect. When the integrity of the structure is in jeopardy, or when **maintenance** is required, the **computer** can notify an operator that help is needed.

Aviation Week & Space Technology

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HEADLINE: Boeing Focusing on Reliability, Low Maintenance for 7J7 Avionics

DATELINE: Renton, Wash.

BODY:

Boeing Co. is pursuing an avionics design philosophy for its planned 7J7 twin-engine transport of the early 1990s that promises to offer dramatic increases in capability and reliability with decreased maintenance costs.

The company plans to make critical decisions next year on the avionics equipment it plans to offer customers initially in its 7J7 transport.

LRU Reduction

Use of avionics incorporating large-scale integrated circuits to provide multiple function capability is expected to reduce the number of line replaceable units in the 7J7 30-50%, compared with existing transports. This reduction in LRUs would allow electronics bays to be less than one-half of their current size, with similar reductions in weight, wiring and power requirements.

Higher reliability of the advanced avionics units is expected to yield mean time between failures (MTBF) of 3-20 times better than that of today's equipment, and reduce the cost of spares by 20-50%.

"We have not settled on a final configuration, by any means. We are developing technologies for the **airplane,** and we'll go through several decision gates to determine which of those are applicable to the 7J7 before we decide to go ahead," James McWha, Boeing Commercial **Airplane** Co.'s 7J7 unit chief, said. "Between now and then, we'll probably discard some items and for others we'll assess what the risks are."

Boeing is almost fully committed to having a fly-by-wire control system in the 7J7, McWha said. "There are economic advantages, and we have the opportunity with fly-by-wire to considerably reduce the pilot's workload in manual flying by the use of certain control laws."

Improvments in handling characteristics that would be facilitated by having a fly-by-wire control system include:

* Flight path angle and track hold, which would allow the flying of an approach, even in turbulence, with only minor corrections by the pilot. Under the flight path angle hold concept, if the pilot releases the flight controls, the fly-by-wire system would maintain the last commanded flight path angle of the **aircraft.**

* Consistent flying qualities over the entire flight envelope of the **aircraft,** as well as throughout the family of 7J7-derivative transports, allowing easier transition of pilots from one **aircraft** to another.

* Flight envelope protection against stall, overspeed and unusual attitudes.

* Automatic engine-out protection, for improved safety during takeoffs and approaches.

McWha said Boeing is considering various flight controllers, including side sticks, for the 7J7 cockpit, and plans to make a decision on controller type by next March. Studies are planned in January, 1987, on Calspan's Total In-Flight Simulator to evaluate candidate control technologies.

Multicolor flat-panel displays, expected to offer a 60-70% reduction in volume and weight, combined with a 50% decrease in cost compared with current cathode ray tubes, are under development for use in the 7J7 cockpit.

Boeing's bidirectional DATAC data bus, which has been under development for the past 10 years, is designed to handle up to 128 line replaceable units on a single twisted wire, thereby reducing the amount of wiring by an estimated 50% or greater, compared with the Boeing 757 avionics system. The number of connectors, as well as the number of pins in the connectors, also is decreased dramatically by use of the 1-megabit/sec. bus.

An early generation of DATAC is installed on National Aeronautics and Space Administration's terminal configured vehicle (TCV), a Boeing 737 that is operated by NASA's Langley Research Center to develop displays and control systems.

The DATAC bus is being developed as an industry standard high-speed data bus by Aeronautical Radio, Inc.A draft Arinc specification has been prepared for DATAC, which is expected to be designated the Arinc 439 bus.

Boeing is working with several suppliers to produce the heart of the DATAC bus, a 9,000-gate custom microcircuit having 170 input/output pins. The company said it also is dealing with a large number of avionics suppliers to install the DATAC bus in existing equipment, replacing Arinc 429 data buses.

Boeing proposes to use six or seven DATAC buses that could be accessed by all of the electronic equipment on the 7J7. About a dozen critical subsystems, such as the fly-by-wire computer, would communicate with three of the DATAC data buses simultaneously for redundance. Less critical equipment such as flight management computers and radios would be linked with two separate buses, leaving one or two buses with which to interface other subsystems.

The 7J7 might have two separate avionics equipment bays -- one in the forward fuselage and one in the tail section -- to provide better isolation between flight-critical systems and to eliminate long runs of cabling. Additionally, electronic units could be located at various points in the **aircraft,** near the systems that they are controlling. "The DATAC bus goes all around the **aircraft,** and that allows you to put the electronic equipment where you can best use it," McWha said. Active cooling of the 7J7 avionics equipment is not expected to be necessary because of low heat dissipation of large-scale integrated circuits.

To further alleviate heat loads, self-contained power supplies may be eliminated from the individual avionics units.The systems would rely instead on high-quality electrical power provided by a central supply on the **aircraft.** Computer memory of the 7J7 avionics systems would be provided by a combination of electrically programmable read-only memory and bubble memory chips, augmented with laser disks for large capacity storage requirements of the central **maintenance computer.**

"We'll probably use fiber optics on the 7J7, but the extent to which we'll use it has yet to be determined," McWha said. Boeing is looking at the possibility of using fiber-optic cabling as the DATAC transmission medium, but "we may or may not make that in time," he said.

Inherent Protection

Fiber-Optic cabling would offer inherent protection from electromagnetic interference caused by high levels of static electricity or lightning in potentially exposed areas, such as in the engine control systems and within the composite structures to be used in the 7J7 tail section.

McWha said the current 7J7 plan specifies the use of fiber optics from the tail of the fuselage, through the engine strut, to the engine controllers in the tail-mounted pods. Use of fiber-optic cabling would reduce or prevent the potential of a lightning strike or other electromagnetic interference affecting both engine control systems simultaneously.

A milestone in this technology was passed recently by the successful use of a fiber-optic engine fuel control on a Boeing 757 testbed.

The 7J7's on-board maintenance system is being designed to reduce ground time between flights and lower the rate of unnecessary electronic unit removals, one of the major problems of today's airlines. The system will have improved capability to identify faulty components. The aim is to improve the ratio of mean time between failure to mean time between unscheduled removal, which is extemely poor at present because "many more boxes are pulled off the **airplane** than are found faulty," McWha said.

Reasons for this problem include the fact that some boxes are not well monitored, and maintenance crews have to make an educated guess as to which ones are faulty. Also, existing monitoring circuits are overly sensitive or are not resistant to the environment, and tend to give false alerts. All avionics units in the 7J7 system are to be monitored, and information is to be transmitted to the central **maintenance computer,** which will display fault information in the cockpit and electronics bays.Maintenance crews also would be provided with unit location as well as replacement and retest procedures by the **computer.**

The maintenance computer potentially would have the capability for transmitting fault information from the **aircraft** to the airline's central maintenance facility during flight via a digital data link, such as the very high frequency Arinc Communications Addressing and Reporting System, to allow ground crews to prepare in advance for needed repairs.

These improvements, combined with extensive use of large-scale integrated circuits for increased reliability of LRUs and improved **fault** tolerance of **on-board computers** through the use of redundancy techniques, "should enable us to bring the [mean time between unscheduled removal] closer to the MTBF, and at the same time, raise the MTBF," McWha said.

The central **maintenance computer** will need only six or seven receivers to communicate with the DATAC data buses of the avionics system, rather than the requirement with Arinc 429 or other buses to provide a receiver for each LRU with which the computer is communicating.

URL: http://www.aviationnow.com

GRAPHIC: Picture, Boeing's digital autonomous terminal access communications (DATAC) high-speed data bus, a 9,000-gate microcircuit contained in a 170-pin package, would be installed in each avionics system line replaceable unit of the company's 7J7 twin-engine transport, which is planned to be introduced in the early 1990s. Photo shows the DATAC bus and a circuit board with three of the devices mounted at its top.; Chart, On-board maintenance system proposed for Boeing's 7J7 transport and diagramed would interface six or seven DATAC high-speed data buses to the central **maintenance computer.** Each data bus would communicate with several avionics subsystems, each containing one or more line replaceable units (LRUs) and associated built-in test equipment (BITE). Critical subsystems would interface to three data buses to assure redundancy in case of system failures, while less critical subsystems would be linked with only one or two buses. The central **maintenance computer** for the **on-board** system would display subsystem status and **fault** information on a printer or control display unit located in the **aircraft,** or send it to the airline's ground crews prior to landing by means of an Arinc Communications Addressing and Reporting System (ACARS) VHF digital data link.

Air Transport World

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HEADLINE: Computers a boon to E&M, but at a price.

BYLINE: Lefer, Henry

BODY:

Computers a boon to E&M, but at a price The promises and problems facing airline engineering and **maintenance** in the **computer** age were on the official agenda of the Air Transport Association's recent E&M Forum in Kansas City. The promises are being fulfilled rapidly, and perhaps that is part of the problem. It takes time to develop the human skills to use the powerful new computer tools efficiently.

Not on the agenda but very much on the minds of the attendees ATW discovered in conversations with E&M chiefs, was the creeping shortage of skilled mechanics and particularly avionics specialists capable of managing the upkeep of the hardware and software of new computerized, digital systems. And the pool of entry-level applicants is drying up as well, the chiefs noted. But they also noted, optimistically, that knowing a problem exists is the first step toward solving it. Whether the situation will get worse before it gets better remains to be seen. In any case, the shortage of personnel has not been felt equally by all airlines. Smaller airlines, commuters and general aviation seem hardest hit. Also, geography seems to play a role. Ray Valeika, VP--maintenance and engineering at Pan Am, suggests that when there are more jobs than bodies to fill them, applicants tend to migrate toward the more attractive parts of the country.

Reasons for shortage

A number of factors contribute to the tightness of the airline M&E labor market. For one, the rapid expansion of some fleets and the post-deregulation birth of new airlines has increased demand. For another, the rapid expansion of airlines into new cities has spread the supply of experienced crew leaders thin. And lastly, as a result of the two-tier wage system which has lowered starting pay, potential applicants can make more money in industries other than the airlines. This has reduced the number of applicants formerly coming from the military, schools and lower-paying sources such as the commuter airlines and general aviation.

In general, the shortage of avionics specialists is real, but that of airframe and powerplant mechanics is still for the most part potential rather than actual. Richard D. Tabery, senior VP-maintenance operations at United Airlines, reports that although the number of airframe and powerplant applicants has dropped, there are still enough to meet United's needs. However, with the large number hired in the last year and a half, the average experience and productivity level has dropped. Tabery figures that the productivity of new hires is only half that of experienced help but increases about 5% a month. G. Edward Ballinger, VP-M&E at Alaska Airlines, says that new hires put on the payroll as a result of the airline's strike last year have dropped the average mechanic's longevity to 10 years from 20. But that's not all bad, he says: The new hires are "eager beavers and very productive."

Northwest Airlines is beginning to feel the shortage of mechanic manpower, says Ben H. Lightfoot, VP-M&E, especially since the enlargement of the carrier's route system. Since less-experienced personnel are not as quick in finding and fixing problems, planes are kept on the ground longer. This is costly, he says. If the shortage does not ease, NWA may have to start its own schools, says Lightfoot.

Delta has no great problem in filling the ranks of its A&P staff, says C. Julian May, VP-engineering at Delta Air Lines, although avionics is getting tight. Valeika says that Pan Am is not yet hurting, but it is getting harder to attract B-scale (the lower wage scale in two tier schemes) A&P applicants and avionics specialists.

Crunch in avionics

May says that Delta is starting to feel the shortage in avionics, especially among flight simulator technicians; personnel with the high skills required by this technology are in great demand outside the airlines. Lightfoot feels the crunch in avionics will grow stronger when the manufacturers' warranties on new avionics "black boxes" expire and the airlines must depend more on their own resources. Sophisticated bench test equipment will help but it is expensive, he says. On the line, Lightfoot is disturbed that many mechanics are still not very good at interpreting readouts of test equipment and are too often pulling components off **aircraft** which later prove out O.K. on the bench. On the brighter side, the new solid-state avionics systems and instruments have thus far proved much more reliable than their electromechanical and vacuum tube equivalents.

Although the new avionics systems require higher skills for maintenance and repair at the deepest levels, the **aircraft** and systems makers have been striving mightily to reduce the skills needed at the line maintenance level. James R. Philliips, chief design engineer of the MD-80/DC-9, told the Forum what Douglas **Aircraft** has been doing in this regard, with particular emphasis on alleviating the mis-diagnosis problem Lightfoot mentioned. About 50% of all components replaced during unscheduled maintenance are found later not to be faulty, Phillips said.

Using the MD-80's digital flight guidance control system as his example, Phillips pointed out that the power of the computers built into the system enabled the designers to provide the system with a multi-talented, user-friendly built-in maintenance test and status capability. This BITE system permits inflight fault isolation down to the LRU (live replaceable unit) level and stores fault data for ground maintenance, testing and analysis.

Heart of the flight guidance system is two identical computers, each capable of completely operating the **aircraft** and each tied to the required **aircraft** systems, sensors and other flight guidance components. An easy-to-operate status panel acts as a centralized interface between the guidance system and the maintenance operator. It has three main functions:

* Return-to-service test quickly performs a built-in routine consisting of seven maintenance test sequences. If it shows a "GO" display on the status panel this indicates that a repair action has been successful and the system is fit to fly. A "NO GO" display indicates a failure, and pressing a button will bring up in the panel's display window the identity of the system causing the problem.

* System maintenance test is normally used after a major maintenance action has been performed affecting the flight guidance system. It is a command-and-response test initiated by the operator. It tests all flight guidance display information in the cockpit, including lights, flags and aural devices; flight crew selectable inputs, including flaps, slats, pushbuttons, course selections, heading selections and switches; checks the values of input sensors and performs a deviation comparison of sensors; checks system nulls, discretes and sensor responses.

If a fault is detected, a fault message and one or more diagnostic numbers appear in the display window. The diagnostic numbers are keyed to a chart in the maintenance manual which explains the fault message, lists the tests used to detect the fault, and provides troubleshooting suggestions, wiring diagram referrals and expected voltage readings.

* Flight fault review provides continuous monitoring of the guidance system and records in memory any failure detected during flight. The failures may be recalled through the status test panel. The memory can store 350 failures over a period of many flights. The system helps track down intermittent as well as hard faults but, Phillips cautions, the relationship between the memory's flight faults and written flight squawks from the crew must be analyzed. A more capable computer program will in the future do some of the analysis and interpretive troubleshooting for the maintenance technicians.

Service Maturity Program

Many other systems on the MD-80 also have their own built-in test equipment, Phillips notes.

On the ground as well as in the air, Douglas **Aircraft** has been able to use the c **mputer** to pinpoint and eliminate **maintenance** problems and optimize in-service performance of the MD-80. The Service Maturity Program tracks over 150 **aircraft** systems based on feedback from the operators. Individual Douglas engineers are assigned to each major system. With the help of the computer the delays from the current fleet of more than 250 MD-80s can be categorized and analyzed so that the engineers can come up with the appropriate fixes and recommendations. In the case of the digital flight guidance computer, this technique resulted in a reduction in the technical delay rate from 1.0 per 1000 departures in 1980 to 0.25 in 1985, Phillips reported.

The Operational Performance Programs mesh **aircraft** performance data with airport case data provided by an airline to produce computer programs for takeoff performance, takeoff speed calculation and maximum landing weights.

The increasing power of the computer and increasing sophistication in its use will enable manufacturers to improve the "design for supportability," as Phillips says, of their transport **aircraft** and further simplify the maintenance technician's job. Already, comparing the DC-9-50 and the MD-80 with respect to the line maintenance rate per flight hour, the use of improved onboard test equipment and digital design has cut the maintenance cost of the MD-80 flight guidance control system to one-sixth that of the DC-9-50 series, says Phillips. He expects the next generation of his company's **aircraft** to show an improvement of the same magnitude.

One of the main reasons for having a mechanic is his ability to perform diagnostics, Phillips says. But as **aircraft** become more complex, even the most highly skilled technician may find it hard to match the reasoning ability of future **onboard** computer systems. According to Phillips, the **computers** will be able to make inferential-type assessments of a **problem**--that is, they will consider the behavior of several components, put them together in a time framework to synthesize a pattern, and then define where the problem exists or is about to exist because of the trend the system is taking.

Another development already underway, but still in its adolescence, is the continuous monitoring of numerous important parameters, much as today's AIDS (Airborne Integrated Data System) monitors engine parameters, and the transfer of the data to ground-based logic computers, either automatically during the flight via an ACARS-type link or on tape for later processing on the ground. On the **aircraft** itself, a single status/test/interrogation panel will serve the whole **aircraft.**

To come back to the present, the automatic capture of airborne data for subsequent analysis on the ground has not always worked out as well as expected. For example, TWA, one of the pioneers in the use of AIDS, ran into problems serious enough to make it consider dumping the whole thing. But the basic idea is too good to abandon and TWA is now restructuring the system, confident that it can fully cash in on the potential of the technique. Terry N. Tykeson, manager-data systems development, traced his airline's experience and described its improvement program.

In a companion paper, Dr. Gerwin Dienger, section manager-powerplant engineering at Lufthansa, another AIDS pioneer, gave an upbeat report on his company's experience on its fleet of Airbus A310s and its plans for enhancing the system.

Although the data access features in the two airlines' host computers are similar, the systems employ different methods of delivering the automatic **aircraft** and engine measurements to the computers and different analytical techniques. But there is no disagreement that automatically acquired airborne data can be used to reduce maintenance costs, improve fleet reliability and make more efficient use of engineers' skills.

Early version of AIDS

TWA's interest in airborne monitoring dates back about 20 years, when it evaluated the technique for its Boeing 707s. However, it wasn't until the 1970-72 period that it got seriously involved with AIDS for its Boeing 747 and Lockheed L-1011 fleets. The main application was engine condition monitoring (ECM), but other systems were also instrumented. These included hydraulics, environmental control, surface controls, air data computers, and inertial navigation systems. Starting in the mid-1970s other applications were introduced, such as crew and **aircraft** monitoring.

The system, still in use today, consists, on the airborne side, mainly of a control electronics unit, three data acquisition units, an incremental recorder and tape cartridge, a five-minute, continuous loop recorder and a data entry panel. On the ground side it consists of four remote data terminals (at JFK Int'l, Los Angeles, San Francisco and Kansas City airports) and a host **computer** at TWA's Kansas City **maintenance** base.

Airborne data is captured on magnetic tape. During overnight layovers at the four airports the airborne tape cartridges are removed from the **aircraft** and the data is transmitted to the host computer. Analytical software is run daily in a batch mode and the resulting reports and microfiche are distributed to the users early in the morning.

Sounds good? The users didn't think so. Reliability of the airborne hardware and remote data terminals was poor, Tykeson said, so AIDS/ECM data was rarely available when required. Reports were too voluminous and took too much time to scan for abnormalities. Presentation did not match what the users wanted. Time between recording and presentation of data was too long for some system functions. The overall system was too inflexible to meet changing needs. With such weaknesses in the system, it's no wonder that many end-users wanted it killed.

Still, with all its failings, TWA says this early version of the AIDS system saved the airline more than $600,000 in 1984 by supplying data that ultimately avoided three major engine teardowns.

So, when the new-generation Boeing 767 began to enter the fleet in 1982-83, TWA resolved to salvage what was good in the system and eliminate what was bad. Key to the upgraded system is ACARS--the automatic air-to-ground communications link. The upgrade was approved last year and is now being implemented.

In the restructured system, the airborne data will be transmitted to the ground by ACARS and processed in real time on an online **computer** system that is integrated with TWA's overall **maintenance** and engineering information system. The **computer** will pass information to the engineer only when it detects a situation that needs his attention. He in turn will be able to call up **aircraft,** engine and other information that he needs via online inquiry at a CRT. Hardware requirements will be reduced.

AIDS/ACARS upgrade

The system upgrade has been more than a matter of simply switching over to ACARS communications and real-time processing. There were fears that the system would be nundated with data and that a tape recording system would still be needed to meet requirements. A study requested by engineering management narrowed down monitoring applications to those with the highest potential benefits. It also indicated that most of the desired monitoring tasks could be supported by data "snapshots" instead of a continuous stream of data. Result: less data would have to be captured and transmitted.

The study revealed that the following functions would yield quantifiable savings if monitored automatically or supported by an automated data acquisition capability: ECM (takeoff exhaust gas temperature margin and divergence, L-1011 VIGV control, power lever margin, engine trim, limit exceedence events, basic engine parameter trends at takeoff and cruise); auxiliary power unit health monitoring; **aircraft** performance monitoring; system integrity (sensor/line replacable unit monitoring); troubleshooting; application development, and evaluations.

Since ACARS coverage is not universal, TWA's AIDS-equipped **aircraft** will be out of ACARS range on transatlantic legs and in Europe. To take care of the former case, the airline is considering storage of messages on-board in non-volatile memory (NVM) until the **aircraft** is within ACARS range. For European coverage, TWA has been discussing with SITA the use of the international telecommunications organization's AIRCOM data link service for real-time coverage.

TWA expects, through the use of ACARS/AIRCOM and the NVM, to eliminate from the AIDS-equipped **aircraft** the incremental recorders, tape cartridges and loop recorders; weight saving will be 60 lbs. per **aircraft.** On the ground the remote data terminals will be decommissioned. However, the system will retain the capability of installing a recorder on each **aircraft** for non-routine engineering evaluations. Also one tape reader will be retained at the Kansas City engineering center to transcribe these evaluation tapes.

Among the many valuable capabilities of the new system is its inquiry/response feature. This is made possible by the ability of the ACARS and AIRCOM networks to transmit data in real time from ground to air, as well as air to ground. The AIDS airborne computer will be programmed to accept an inquiry and respond appropriately. The possibilities are exciting, says TWA--for instance, real-time en route troubleshooting.

Lufthansa ECM system

Implementation costs for the planned AIDS/ACARS upgrade are $1 million for airborne hardware and software, and 10 man-years for developing ground software. Annual operating costs are estimated at $120,000 for the planned system and $423,000 for the current system. Offsetting these costs, TWA estimates the benefit for its existing fleet as over $3 million a year. TWA expects the new system to become a reality toward the end of this year.

Lufthansa, along with British Airways, KLM, SAS, Swissair and others, has been developing AIDS/ECM applications for some years. LH's ECM program is based on G.E.'s GEM (ground-based monitoring) program. Drawing on its own 15 years of experience. Lufthansa emphasizes that "the secret of a successful ECM system is to have the right data at the right time at the right site."

Gerwin Dienger's presentation to the forum described how Lufthansa achieves these three "rights" on its fleet of A310s. With regard to "the right time," Lufthansa depends on what Dienger calls "the poor man's ACARS." Unlike TWA's real-time air-ground data transmission, Lufthansa uses an airborne printer aboard its A310s. The data, which used to be entered by hand by the flight crew, is automatically printed out in OCR (optical character recognition) format. At the end of each flight the printouts are handed to station personnel, who use a hand-held video scanner to automatically transmit the information to Lufthansa's main base at Hamburg where it is processed in realtime.

The "right data," of course, are those bits of information needed for the analytical tasks that Lufthansa has identified as the most rewarding ones. On-ground tasks include extended condition diagnosis and monitoring down to the engine module level with respect to performance and vibration.

On-board tasks include limited health monitoring for short-term recognition and recording of engine operating abnormalities. In order to fulfill ECM requirements on the module level, Lufthansa has installed expanded instrumentation, including a PMUX (powerplant data multiplexer) on its CF6-80A3 engines.

The "right sites" to which data is delivered as Maintenance Engineering at the Frankfurt main base, and the powerplant workshop and test cell to Powerplant Engineering at the Hamburg base.

Maintenance Engineering issues alert summaries automatically, and engine and module trends on request. The powerplant workshop, which uses data for production planning and control, supplies historical engine and module trend printouts on request; the workshop's test cell processes test run records and runs simulations on request. Powerplant Engineering uses the data to arrive at fleet averages per engine type, long-term trends and other statistics.

As in the TWA system, engineers automatically receive only significant information such as alerts and can access the data base for supporting information.

Lufthansa has invested $1.1 million thus far in development and implementation of its A310 ECM system (but, Dienger notes, new fleets will also use the system). Operating cost is figured at $5,000 per **aircraft** per year. Offsetting this, Lufthansa estimates quantifiable savings at $50,000 per **aircraft** per year. Non-quantifiable benefits include improved troubleshooting effectiveness with reduction of out-of-service times and shifting of maintenance tasks from unplanned to planned; improved flight/ground crew communications and relations; improved flight safety; and reduced environmental impact through elimination of many ground engine test runs.

Future improvements

Lufthansa plans to develop the current system further, Dienger reported, to cover more engine/**aircraft** combinations, and to incorporate programs now in development for the auxiliary power unit and airplane performance monitoring. He also noted that next-generation engines will be equipped with FADEC (full authority digital electronic control) which will include fuller engine instrumentation. The installation of a separate PUMX to monitor engine main modules will

therefore no longer be required. Also in Lufthansa's planned development is the switchover to ACARS/AIRCOM telemetered data flow in place of its present "poor man's ACARS."

Dienger completed his presentation with the observation that close cooperation among the airlines and manufacturers of **aircraft,** engines and systems is a must for the effective development and introduction of extended monitoring systems.

Chairman of the forum was Jack B. Le Claire, Jr., VP-maintenance and engineering, TWA. The 1986 forum, to be held in Atlanta, Ga. Sept. 29-Oct. 2, will be chaired by Donald P. Hetterman, senior VP-technical operations, Delta Air Lines. The 1987 forum will be held in Cincinnati, Ohio.

GRAPHIC: Photograph

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HEADLINE: Simulation Techniques Converging To Meet Military, Commercial Needs

BYLINE: By Kenneth J. Stein

DATELINE: New York

BODY:

Technology advances in three principal areas are converging to enhance the ability of flight simulation systems to meet the respective requirements of total mission simulation training for the military and cockpit resource management for commercial airlines.

Key developments contributing to improved simulation effectiveness in the near future are expected to fall into these areas:

* Visual systems -- encompassing image generation and display -- in which continuing improvements in field-of-view capabilities and realistic detail are anticipated.

* Emergence of distributed processing techniques, now being applied to the entire simulator operation, as well as driving the visual presentation. "Computing is reaching the stage where the large host mainframe is coming to the end of its time," one executive said. Moves to develop distributed processor technology, such as the Seagull program agreement between Rediffusion and Gould's Computer Systems Div., Ft. Lauderdale, Fla., point a likely direction for future simulation hardware (AW&ST Sept. 17, 1984, p. 87). Accompanying multiprocessor development, however, will be an increasing logical challenge to develop complex software.

* Improved instructor station capabilities, which will simplify the instructor's task, allowing more time for management of simulation exercises. Artificial intelligence technology is expected to come into play in this role, along with interactive systems using techniques such as touch-screen inputs.

Simulator manufacturers agree that the visual area is benefiting from important technological developments.

A strong driver has been the military marketplace, where effective simulation of low-level nap-of-the-Earth missions emerged as an important requirement.

At General Electric Co.'s Simulation and Control Systems Dept., for example, the focus has been on the high end of the market, providing accurate imagery for nap-of-the-Earth military helicopter missions, according to C. C. (Skip) Christ, program general manager for flight simulators and digital controls at the Daytona Beach, Fla., operation.

General ectric's first customers have been in the military field, including Compu-Scene 2 visuals for West Germany's Panavia Tornado strike-reconnaissance **aircraft** simulators and for USAF/Lockheed C-130 flight simulators built by Singer Co.'s Link Flight Simulation Div.

Use of very large scale integration (VLSI), however, is expected to shrink the system, Christ said, and resulting reductions in cost, combined with training capabilities that meet Federal Aviation Administration Phase 3 standards, could make the product very attractive for commercial use, Christ said.

Recent orders for GE's current CompuScene 4 hardware have been largely for installations on advanced research simulators. First Compu-Scene 4 customer, McDonnell Douglas Corp., will install three of the visual systems in simulator domes at the McDonnell **Aircraft** factory in St. Louis; a fourth system will be used in a new Hughes Helicopter simulator facility expected to be operational next year (AW&ST Jan. 14, p. 153).

A Compu-Scene 4 will be installed in a helicopter research simulator also expected to be operational next year inside a 20-ft.-dia. dome at Sikorsky **Aircraft** Div. of United Technologies Corp.

General Electric recently received a $7.9-million order from Lockheed-California Co., Burbank, Calif., for a CompuScene 4 visual system to equip a new research facility at Rye Canyon.

The Lockheed purchase includes a six-channel image generator and a data base generation station, used to convert raw data, such as Defense Mapping Agency geographical information.

A Compu-Scene 3 system has been ordered to upgrade the Navy's 2E6 combat simulator at Oceana Naval Air Station, Oceana, Va. This $5.5-million contract provides for two dome displays that permit two pilots to simulate combat against each other in Navy/McDonnell Douglas F-4 or Navy/Grumman F-14 **aircraft.**

Christ anticipates a large retrofit market to provide high-quality visuals for USAF/Fairchild Republic A-10, McDonnell Douglas F-15 and General Dynamics/Ft. Worth F-16 **aircraft** simulators.

General Electric is also working with the Naval Training Equipment Center on a comprehensive distortion correction technique that would pre-distort imagery in the image generator to take into account the curvature of the dome into which the image is projected, and is also working with Air Force researchers on cell texturing techniques, using a joint USAF/Army demonstration testbed, Christ said.

Link Flight Simulation Div. continues to rate visual development as one of the biggest logical challenges, although software development is not far behind, according to R. N. Hendricks, vice president-technical director.

Link applied microprocessor technology to simulator visuals with its Image 2 system, first installed on a Link-built McDonnell Douglas DC-9 Phase 2 simulator at USAir's simulation center at Greater Pittsburgh International Airport (AW&ST Apr. 23, 1984, p. 177).

The company is moving toward application of distributed microprocessor technology to the overall simulator, not just the visual portion of the system.

Link is also developing a new visual system, in transition from proof of concept to a full-scale development system, at its Binghamton, N.Y., plant. The system provides an area of high-resolution imagery, covering about 20 deg., that moves to wherever the subject's eyes are directed within the overall visual scene, according to Hin-Man Tong, Link's director-visual systems (AW&ST Jan. 14, p. 161).

Link is developing other wide-angle visual technology for possible application to simulators for military tanker **aircraft.**

Digital processing is also being applied by Link to the **problem** of electronic warfare simulation, Hendricks said. This formerly required much **on-board** equipment for the simulation, but now can be done digitally at the **computer** level, he said. The tradeoff, inevitably, is more software, Hendricks said.

"Software is expensive and complex," he said. "Our software goes on and on and on."

Large simulators go into hundreds of thousands of lines of code, all operating in real time, and the development process requires millions of lines of code in the support environment. In a complex simulator, like the USAF/Boeing B-52G/H system, at any instant there are several versions of code to conform to differing configurations, Hendricks said.

Rediffusion Simulation's Wide (wide-angle infinity display equipment) system, first introduced in 1982, provided a 150-deg. horizontal field of view (AW&ST Sept. 6, 1982, p. 210). The company's new Wide 2, with a horizontal field of view expanded to 200 deg., has been ordered by the U.K. Ministry of Defense for a helicopter training requirement.

The company does not consider this degree of coverage "appropriate to the standard commercial product."

In the U.S. environment, however, improved visual display techniques are facilitating joint flight crew activity sought in the Federal Aviation Administration's cockpit resource management approach, which seeks to improve management roles on the flight deck, according to David Shorrock, vice president-marketing and product development at Rediffusion Simulation, Inc., Arlington, Tex., U.S. affiliate of the U.K. company.

In earlier systems, each pilot essentially has had an independent display, making it relatively ineffective for cross-cockpit operations and checks, Shorrock said.

Phase 2 Operation

Rediffusion has sold 22 Wide systems to date. The first system, in operation at Delta Air Lines, is being upgraded for FAA Phase 2 operation.

Although relatively few Phase 3 full daylight systems are in use in the U.S., interest has been strong in other countries, according to Shorrock.

The company is using computer technology to broaden its product base, offering **computer**-based instruction for pilots, **maintenance** workers and others, with double utility software serving both the flight simulator and providing mathematical models of some equipment for ground training systems. This would permit the simulator to be used in the most effective way, while employing the same software for training in some jobs outside the prime simulator, Shorrock said.

Rediffusion participated in a demonstration for USAF Tactical Air Command last year, during which an advanced visual system was applied to a Goodyear Aerospace McDonnell Douglas F-15 flight simulator in a joint program involving Goodyear, Rediffusion and Evans & Sutherland (AW&ST June 11, 1984, p. 72).

The F-15 exercise led to advances for Rediffusion in the sensor part of simulation, Shorrock said. Primary visual references will be in the cockpit, with a greater need for a computer-generated data base onboard the **aircraft,** he said. "We need to get a common data base between the sensor systems and the out-the-window view," Shorrock said. "This will be a transportable data base, suitable for the F-15E or the dual-role fighter."

Mapping Data

Rediffusion has found an effective way to incorporate Defense Mapping Agency data into the simulator data base. The technique is being developed as a collaborative effort with Goodyear and Evans & Sutherland, Shorrock said.

Another growth area is in regional airline training systems. Rediffusion is building the first two simulators for the British Aerospace 146 transport, one for British Aerospace and the other for Pacific Southwest Airlines, which will have FAA Phase 3 capability. The company expects that **aircraft** type transitions would become a Phase 3 operation.

URL: http://www.aviationnow.com

GRAPHIC: Picture 1, Rediffusion Simulation's Wide (wide-angle infinity display equipment) fitted to a British Airways Helicopters BV234 Chinook simulator shows computer-generated image of an approach to an offshore oil rig. Imagery is derived from Novoview SP1 system.; Picture 2, Exterior view of BV234 Chinook helicopter simulator built by Rediffusion for British Airways Helicopters shows large enclosure for 150-deg. Wide visual system.

Aviation Week & Space Technology

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LENGTH: 3075 words

HEADLINE: 'Total Simulation' Seen in Training

BYLINE: By Kenneth J. Stein

DATELINE: London

BODY:

Increasing emphasis on airline flight training conducted in new technology flight simulation systems, driven by compelling safety and, more recently, economic incentives, is receiving strong new impetus this summer with the long-awaited formal rulemaking on advanced simulation by the U.S. Federal Aviation Administration.

The move toward "total simulation," Phase 3 of an incremental program that would lead to providing 100% training in simulators, followed by routine line checks, has been seen by airline training executives as offering major advantages in safety, quality of training and energy conservation (AW&ST Nov. 12, 1979, p. 191).

Major simulation equipment manufacturers in Europe see the Faa Rulemaking as a spur both to new system sales and to the upgrading of older simulators with advanced computer-generated visual systems and other improved technology.

"We have examined the [advanced simulation] documents and, of course, been a partly to them, and we are clearly in a favorable position to make an early commitment to Phase 3," J. W. N. Yoemans, managing director of Redifon Simulation, Ltd., told Aviation Week & Space Technology.

Basic Product

"The industry is close to matching Phase 3 developments," according to Yoemans. Redifon's SP2 computer-generated visual system, which employs a high-resolution, high-brightness shadow mask cathode ray tube to display night, dusk and full daylight scenes, is the basis of its visual product, Yoemans said. "Detailed development programs are in motion," he added.

The Crawley, England, company delivered its first SP2 systems to Lufthansa German Airlines for use at the carrier's Frankfurt training center. Redifon's Novoview SP concept provides for upgrading a night/dusk SP1 system to incorporate the full daylight capabilities of an SP2 and to expand the visual presentation to encompass a wider field of view.

At Link-Miles in Lancing, England, Peter Astley, technical director, pointed out that "no customer asks for less than Phase 2 these days." Basically, new simulation equipment is inherently capable of fulfilling FAA advanced simulation requirements, Astley said.

Although the FAA rulemaking has regulatory force only in the U.S., "other countries are obviously taking note," Astley said.

In France, new computer-generated visual systems are being readied for the civil market, according to Jean-Pierre Chautard, sales manager at Thomson-CSF Simulators LMT, formerly known as LMT Simulator and Electronic Systems Div.

Thomson-CSF Simulators, at Trappes, France, has developed its own specialized high-speed processor for computer-generated visuals and now has a night/dusk system, Chautard said. The company plans to introduce a full day/night system for civil and military use, according to Chautard.

Pursuit of Phase 3 capability is generally conceded to require both better visual systems and improved **aircraft** data.

Regarding the retrofit market, Redifon's Yoemans expects that users would have to go to a full day/night SP2 system.

Although the FAA rulemaking provides an incentive to improve earlier machines, "not all early simulators can be upgraded to perform the landing maneuver requirements," Yoemans said. "Some users may have to limit their ambitions with older equipment to Phase 1 operations, using an SP1 night/dusk capability," he said.

Although the simulation market has experienced its ups and downs, Redifon's business has reflected a fairly stable 40% of the world market, according to Yoemans.

Total backlog for 1980-81 for the Redifon Simulation group of companies -- including Arlington, Tex. -- is about $215 million, according to Yoemans. The company is moving toward sales of $95 million in the United Kingdom, he said.

Current simulator production nearing completion at Crawley during a visit by Aviation Week & Space Technology included:

* A McDonnell Douglas DC-10 for American Airlines.

* Two Boeing Advanced 737-230s for Lufthansa German Airlines.

* A Boeing 747 with SP1 visual system for Aerolineas Argentinas.

* A Boeing 727 for Libyan Arab Airlines.

* A 727 for Western Airlines.

* A 737 for Boeing Commercial Airplane Co.

* Another Boeing 737 for Braathens SAFE.

The company is also producing Panavia Tornado simulators with three-axis motion systems, mounted in transportable containers. A new order is for a Boeing-Vertol Chinook helicopter for British Airways, Aberdeen, with an SP1 visual system providing a four-window display.

As a result of the "pressure" developing from FAA's recent rulemaking, "we expect exciting developments in simulation in the next few years," according to S. J. Anderson, Redifon development manager.

There is also developing interest in the "theatricals" of simulation, including "odd little noises," **aircraft** sounds and vibration, changing ambient light levels and rain and snow simulation effects, according to Anderson.

"We ought to do all of these, but no one will be prepared to pay too much money for these effects," Anderson said.

Anderson sees a technical trend toward parallel processing of some kind in future systems. "Is it right to use a main processor at all?" he asked. One approach might use multiple processors in parallel, with a managing processor supervising a common family of similar parallel processors, according to Anderson.

There are still a number of analog areas, such as motion, control loading and sound cues, he said. These are still analog because they cannot be handled readily by a digital computer.

Parallel Operation

Marketplace advantages in terms of better diagnostics, high availability and reliability might result from using a very high speed digital processor in parallel with a main computer, Anderson said.

This could also reduce life cycle costs and provide a "self-healing" system.

In developing its new technology, Redifon adopted complementary MOS logic, but did not go as far as it could have, according to Anderson. "What does it do of the user if you put the simulator avionics in a matchbox?" he asked.

Prime potential advantage is if the reduced size of the system avionics also reduce costs without any sacrifice of reliability and maintainability, Anderson said.

First complete new-concept technology simulator system produced by Redifon is a Boeing 747 for Japan Air Lines. The JAL simulator embodies all of the major technology improvements, including hydrostatic motion and control loading systems, modular advanced graphics generation system (MAGGS) instructor facilities, Novoview **computer**-generated image displays, advanced **onboard** avionics interfaces and integrated maintenance **diagnostics,** Anderson said. The system uses a 32-bit processor.

"Rarely does anyone ask any longer, 'why 32 bits?'" Anderson asked. The answer, he said, is not in steady-state performance, but in second- and third-order effects.

"This is an enormously complex set of data being manipulated," Anderson said. "One of the benefits of the 32-bit machine is that it can solve integrations in a more parallel way and is better able to perform operations simultaneously." The 32-bit processor can take the user as far ahead as possible, Anderson said.

New Options

The MAGGS modular instruction and software philosophy expands customer options, and can even provide automatic lesson plans, Anderson said. However, it puts stringent demands on the user to plan what he intends to do with his training capabilities. A flight instructor, using a hand-held controller slightly larger than a hand calculator, can sit on a cockpit jump seat and monitor the pilot, just as he would in an actual **aircraft,** Anderson said.

The emphasis now in simulation is to use the performance of the computer to simplify the instructor's task, Anderson said.

"The user wants system sophistication working for him in the background with a nice, logical, non-engineer type console," Anderson said.

"My reading of customer comment is that a number of airlines say they want less, rather than more, sophistication," he said.

Redifon is developing laser-based visual system, but it is slanted toward military applications.

"I don't see the form of visual system we're developing as applicable to the commercial field," he said. "It presents a continuous scene with extremely wide visual angles, directed toward military needs."

The increasing number of new black boxes on commercial **aircraft** are also impacting on simulation, Anderson said. "At the present time, we stay with actual **aircraft** black boxes until the system designs stabilize," he said. "In the future, we may tackle simulation of black box equipment on a case-by-case basis."

An accompanying trend is the rapidly growing tendency to replace conventional **aircraft** instruments with cathode ray tube displays and related avionics. Ultimately, present-day analog instruments may virtually vanish, dictating a need for interface changes in which the **aircraft** manufacturer's computer will be coupled directly to the simulator manufacturer's computer, Anderson said.

Thomson-CSF Simulators LMT has seen "tremendous growth in sales this year," with many users replacing earlier simulation systems to provide new training capabilities, according to Chautard.

About 60% of the business is export, compared with about 43% for the parent Thomson-CSF company.

Evolutionary changes in the Thomson-CSF products are directed toward meeting new training requirements, including improvements in **aircraft** mathematical modeling.

Emergence of the total simulation concept, including detailed landing maneuver performance requirements, has raised a universal call from simulator manufacturers for more complete **aircraft** performance data.

Heavy Export Market

Current production at Thomson-CSF Simulators during a visit by AVIATION WEEK & SPACE TECHNOLOGY included Airbus Industrie A300 **aircraft** for Scandinavian Airlines System, undergoing on-site checkout; Aeroformation training center at Toulouse; Thai Airways; Air France, and Eastern Airlines.

Other customers include Iberia, Indian Airlines, Garuda Indonesian Airways, Malaysian Air Systems and Trans-Australia Airlines. An Air France Boeing 727 simulator is also on order.

All of the current large simulators are on six-axis motion bases built to provide large excursions.

Thomson-CSF Simulators is also building simulators with six-axis motion bases and visual systems for the Dassault-Breguet/Dornier Alpha Jet trainer/ground support **aircraft** for an export customer.

The company presented a computer-generated visual system for military applications at the 1979 Paris air show and expects to have a civil version in the near future.

The Thomson-CSF A300 simulator provides two instructor stations with color cathode ray tube displays for systems information, including flight conditions and environmental data. The two stations provide for separate instructors for pilots and flight engineers, who may be trained separately during the same "flight."

The A300 for Aeroformation incorporates a McDonnell Douglas Vital 4 six-window visual system.

For the Alpha Jet simulators, the instructor's stations provides two cathode ray tube displays and associated keyboard, including a panel for weapons training.

The Alpha Jets use Thomson-CSF's own visual system and are mounted on a small six-axis motion base. The main computer is a Systems Engineering Laboratories 32/77, with a Thomson Mitra computer employed for visuals. The Alpha Jet simulators also incorporate digital control loading.

The system can provide hard copy recording of **aircraft** flight and can play back standard flight phases for training demonstrations, Chautard said.

The company hopes to receive a major order for its digital radar land mass simulation equipment in the near future and continues to perform digital map contouring for French government agencies.

Helicopter orders at Thomson-CSF Simulators include an order for 16 trainers, mainly for the Aerospatiale SA 341 Gazelle and an export for a simulator for an Aerospatiale SA 330 Puma helicopter.

Additional Facility

Shifting of simulator production for military tanks, nuclear power plants, submarines and ship navigation to another factory has opened a large high-bay area at Trappes for construction of large **aircraft** simulators on large motion bases.

Link-Miles at Lancing, England, is completing a number of wide-body transports, including a Kuwait Airways Boeing 747 with dual instructor stations that has been accepted and is waiting final shipping approval. The company also is completing 747s for Flying Tiger Line and Thai International, as well as Lockheed L-1011s for British Airways and Pan American World Airways. The Pan American simulator has also completed acceptance testing.

Link-Miles is also building the first of three Lockheed C-130 military transports for the Royal Air Force, incorporating Singer-Link advanced simulation technology (AST) design concepts (AW&ST Aug. 23, 1976, p. 60). The company's contracts for commercial AST systems now total 25, according to Astley.

New Simulators

AST concepts are also being applied in two new simulators for the British Aerospace Sea Harrier, one for the Royal Navy and one for another customer. The Sea Harrier work benefits from Link-Mile's earlier experience in building AV-8A Harrier simulators for the Royal Air Force. The company also built Harrier simulator equipment for the U.S. Marine Corps.

The Sea Harriers will be mounted on a six-axis motion base and "will really exercise the motion system thoroughly," according to Astley.

The simulator will be equipped with dusk/night visual imagery, with a three-window display system providing the side view of the ground required for training in VTOL operations, Astley said. The system provides all flight cues for hover-mode operations.

The system uses a Perkin-Elmer Inter-data computer, which is already in the British Ministry of Defense Inventory, he said.

The Sea Harrier simulator will be fitted with a number of actual equipment black boxes integrated in the **aircraft,** including a Smiths Industries head-up display (HUD), Ferranti Blue Fox airborne radar system and a Plessey weapons delivery system, Astley said.

A massive instructor console is included in the Sea Harrier simulator system, in accordance with the customer's request, Astley said. The console provides repeater displays of night vision system and HUD imagery for the instructor.

No Instructor

"In the Sea Harrier, you can't put an instructor behind the pilot," Astley said.

One end of the instructor's station is equipped as a "student training station," including a stick for control of the **aircraft,** and controls for radar, electronic warfare, weapons systems, HUD and nav/attack systems, which the student may learn to use under close supervision.

Link-Miles is also working with Westland Helicopters, Ltd., on a WG.34 helicopter simulator, which will be used as a development tool to aid in development of the **aircraft,** according to Astley.

The simulator is designed to predict probable **aircraft** performance, reducing the number of flight hours, Astley said. Simulator inputs will provide for modifying parameters of performance equations, using a straightforward mathematical model.

Link-Miles is developing the software for the WG.34 system and is building the control loading system, while Westland is building the **aircraft** fuselage.

The system will be an ongoing program, even after delivery of the **aircraft,** Astley said. Link-Miles expects to work closely with Westland as the helicopter system evolves and will probably add a motion base to the simulator in the future. The simulator has been designed to accept a motion system.

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SECTION: SPECIAL REPORT: U.S. AIR FORCE; Research and Development: Changing Patterns; Pg. 45

LENGTH: 4653 words

HEADLINE: Technology Spurs Weapon Gains

BYLINE: By Clarence A. Robinson, Jr.

DATELINE: Washington

BODY:

Technology now in the embryonic stages is emerging from U.S. Air Force research and development laboratories and the aerospace industry which will radically change the patterns of weapons system development and acquisition.

Weapons system application that will reflect these changes include:

* Fighter **aircraft.** Significant performance gains will be achieved in terms of speed, maneuverability, reduced weight and greater fire power. The gains will stem from fiber optic data links with electro-optics, microcomputers and high powered compact laser weapon systems.

* Space systems. Exploitation of space looms as a probability with military manin-space missions in the Rockwell International/NASA space shuttle transportation system. Transmission and retrieval of data will increase for spacecraft with the increased bandwidth potential of optical transmission and the payload capacity of the shuttle and inertial upper stage.

* Strategic missiles. Greatly improved understanding of combustion stability effects through laser Doppler anemometry and other advanced techniques will evolve in the next 10 years. Interest will be renewed in the use of high energy propellants, and in exotic propellant formulations such as metastable hydrogen. Carbon/carbon materials will be used increasingly for upper stages with extendable/expandable exit cones, and advanced thrust termination for solid rocket propellants.

* Tactical missiles. Variety of sensors such as millimeter wave length, imaging infrared and radiometric correlators will be used for all-weather, standoff delivery. Low visible, radar and infrared signature propellants will be used with increased burning rates of about 10 in./sec. at 1,000 psi. Ultrashort propellant consumption times will be available with complete burnout within the launch tube.

Gen. David C. Jones, Chairman of the Joint Chiefs of Staff, and former Air Force Chief of Staff, told AVIATION WEEK & SPACE TECHNOLOGY that he is more convinced than ever that this is a revolutionary period in terms of data collection, micro-processing and dissemination of information.

He said he believes that within a few years computers will have even more of an impact on daily lives and production of new military systems. The real requirement now, Gen. Jones said, is to combine the available information, assemble it in real time and provide it to political and military commanders so that intelligent decisions can be made on world-shaping events.

'Watching the Battle'

"The airborne warning and control system (AWACS)," Jones explained, "collects tactical information and provides it to the commander in real time. It's just like having the commander standing on a hill watching the battle, only in this case it's the air battle and he sees things in real time. And he need not be in the **aircraft** since the information can be

provided via downlink. The commander doesn't get all the information, but he gets what he needs displayed accurately."

The greatest requirement today, according to the chairman, is to fuse the abundant amount of information available in the areas of command, control and communication with reconnaissance capabilities. Jones wants more information on the enemy available for all the services. "There is too much information available on the enemy's strength, and not enough on his weaknesses -- we need to know his Achilles heel."

This position has lead to real time reconnaissance efforts in the Air Force, both tactical and space-based.

In general, Jones believes that efforts in the U.S. have slacked in the area of basic research and it concerns him. The trend, he said, is toward applied research, and it bothers him that more capital is not being invested in basic science areas. "In our society the money goes where the rewards are the greatest, and the penalty for failure is getting so great that we need to have higher rewards for success and lower penalties for failure."

There is now a great reluctance to develop programs with high risk, but more work should be done in areas where the end is not in sight, he believes.

The lightweight fighter program with the F-16 and F-17 is an example he cited which started with no weapons system in sight. "As a result, we got two of the hottest fighters in the world," he added.

All-weather and night operations for tactical fighters and short takeoff capabilities with combat loads are areas, Jones said, that are being pressed for near-term application. Fighters such as the McDonnell Douglas F-15 and the General Dynamics F-16 can operate with under a 1,000-ft. takeoff roll with a formidable air-to-air weapons load. USAF is now studying mobile barriers and arresting gear systems to provide STOL (short takeoff and landing) capabilities for combat operations, especially in the European theater.

Many of the technologies now taken for granted came to fruition over a 20-year period from 1937 to 1957 through a bulging U.S. technology base: nuclear weapons, jet engines, radar, inertial navigation systems, computers and nuclear energy. Jones is concerned that other nations are now moving toward the leading edge of technology, particularly the Soviet Union, through increased research and development spending.

There is great synergism between seemingly unrelated technologies, and there are always unexpected breakthroughs, Jones said. The concept of devoting this special issue to USAF research and development began with Gen. Jones when he pulled a small nuclear magnetic bubble from his shirt pocket and described it to AVIATION WEEK & SPACE TECHNOLOGY editors as the next generation gyro for fighters.

Diversity in Backgrounds

Since that time Gen. Lew Allen, Jr. has become Air Force Chief of Staff. Allen is a nuclear physicist, and it pleases Jones that there is a diversity in the backgrounds of those responsible for USAF research and development. Gen. Alton D. Slay, commander of Systems Command is an armaments developer, and Lt. Gen. Thomas P. Stafford, deputy chief of staff for research, development and acquisition, is a test pilot and Gemini/Apollo astronaut. The backgrounds of these Air Force leaders are particularly well suited for technology areas where emphasis is being applied -- energy, armaments, laser/particle beam weapons research, and manned/unmanned space systems.

The Air Force laboratories are teamed with industry and other service laboratories to provide research in a number of areas that will bolster the sagging basic science work Jones now worries about.

The USAF laboratories are controlled by System Command director of science and technology, Brig. Gen. B. D. Ward. There are 13 laboratory complexes with funding of about $1.1 billion every fiscal year.The current Fiscal year involves:

* Basic research -- $104 million.

* Exploratory development -- $376 million.

* Advanced development -- $184 million.

* External sources -- $300 million.

Some Air Force organizations and their major efforts include:

* Armament Laboratory, Eglin AFB, Fla. which is seeking to advance the state-of-the-art in conventional munitions to meet the postulated Soviet threat in the 1980s of massed armor in Europe. Emphasis is on self-forging fragment warheads designed to penetrate armor out to 50 ft. at velocities greater than 6,000 fps. Low-cost adverse weather seekers such as millimeter wavelength contrast guidance are being developed for terminal guidance against armor.

* Avionics Laboratory, Wright-Patterson AFB, Ohio, working in areas of electronic/electromagnetic devices, reconnaissance, navigation and weapons delivery, and active and passive electronics warfare. This lab is developing the electronic agile radar for operating modes which include high resolution mapping using synthetic aperture radar, terrain following/avoidance and intertial navigation. The radar has a growth capability for air-to-air use. The all-weather tactical strike system is being developed for fighter **aircraft** in the late 1980s for improved radar weapons delivery while operating in a dense electronic warfare environment. A magnetic bubble memory also is being developed as a replacement for magnetic disc, drum and tape recorder systems. The device requires less space and has built in fault tolerance.

* Aeropropulsion Laboratory, Wright-Patterson AFB, is working in major areas of turbine and ramjet engines, power-electrical, mechanical and hydraulic systems for **aircraft** and spacecraft, and fuels and lubricants. Advanced technology engine work is in progress to provide higher thrust per weight and volume with lower support costs.

* Flight Dynamics Laboratory, Wright-Patterson AFB, where work is being accomplished in the joint USAF/NASA program to verify drag reduction and resultant fuel savings from the use of winglets. Based on the useage rates of the Boeing KC-135 tanker fleet, USAF believes it could save 43 million gallons of fuel per year by using winglets. Advanced composite structures for missiles are being developed to reduce reentry vehicle substructure weight by 20% and provide a 30% cost savings. The advanced fighter technology integration program of the laboratory is designed to couple the fire control and flight control systems to enhance weapons accuracy and fighter survivability.

* Materials Laboratory, Wright-Patterson AFB, is working in areas of manufacturing technology, thermal protection materials, aerospace structural materials, propulsion materials and protective coatings. Particular attention is being paid to work with industry to design and operate production plants of the future where robotics are used to construct parts and assemble **aircraft.**

* Geophysics Laboratory, Hanscom AFB, Mass., which is delving into upper atmosphere density, reentry vehicle erosion, ionospheric propagation and spacecraft charging technology. At geosynchronous altitudes a high negative charge potential is built up on the dark side of the spacecraft, while the sunlight side remains near zero. When the current discharges, electromagnetic interference results and causes disruptions or total satellite failure. The program effort is aimed at overcoming this problem by refining environmental specifications for satellites.

* Human Resources Laboratory, Brooks AFB, Tex. where major tasks include flight simulation training, **computer**-based instructional systems, **maintenance** simulation training and human resources in systems design.

* Rocket Propulsion Laboratory, Edwards AFB, Calif., seeking to provide longer lifetimes and improved propulsion for satellites and spacecraft, and develop booster and payload propulsion for advanced ballistic missiles and high performance advanced propulsion concepts.

* Rome Air Development Center, Griffiss AFB, N.Y., where digitally coded radar, automated intelligence processing, anti-jam communications, tactical electronic counter countermeasures radar, and emitter location and strike systems work is being accomplished.

* Weapons Laboratory, Kirkland AFB, N.M. where high energy laser weapons work is being accomplished on the USAF/Boeing NKC-135 airborne laser laboratory. USAF officials also envision the use of ground-based high energy